ARL-TR-9 AR-007-077

AD-A260 689

AUSTRALIA

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

Technical Report 9

IN-FLIGHT EVALUATION OF NOISE LEVELS AND ASSESSMENT OF ACTIVE NOISE REDUCTION SYSTEMS IN THE SEAHAWK S-70B-2 HELICOPTER

by

R.B. KING
D.A. FORAN

Approved for public release.

NOVEMBER 1992

AR-007-077

DEPARTMENT OF DEFENCE
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
AERONAUTICAL RESEARCH LABORATORY

Technical Report 9

IN-FLIGHT EVALUATION OF NOISE LEVELS AND ASSESSMENT OF ACTIVE NOISE REDUCTION SYSTEMS IN THE SEAHAWK S-70B-2 HELICOPTER

by

R.B. KING
D.A. FORAN

SUMMARY

Cabin and at-ear sound spectra in the S-70B-2 at various crew positions and flight conditions were measured in order to determine the noise attenuation properties of the ALPHA helmet and the effectiveness of active noise reduction (ANR) systems developed by the Defence Research Agency - Aerospace Division (formerly the Royal Aerospace Establishment) and the BOSE Corporation. Results show that if newly proposed hearing conservation guidelines are adopted, aircrew wearing the ALPHA helmet would require additional attenuation devices. It is recommended that an ANR system be incorporated into the S-70B-2 as such a system would allow realistic flight duration to be maintained. improve voice communication, and reduce aircrew fatigue.

DSTO AUSTRALIA

POSTAL ADDRESS: **Director, Aeronautical Research Laboratory**
506 Lorimer Street, Fishermens Bend 3207
Victoria Australia

CONTENTS

1. INTRODUCTION

1.1 Noise Levels in the S-70B-2

As part of the Design, Test and Evaluation procedure for the S-70B-2, the Aeronautical Research Laboratory (ARL) has been involved in the investigation of noise levels experienced by aircrew. A preliminary study conducted by ARL indicated that cabin noise levels in the S-70B-2 are such that the Royal Australian Navy (RAN) Advanced Lightweight Protective Helmet for Aircrew MK IV (ALPHA helmet) does not provide adequate hearing protection for aircrew (ARL Letter Report M2/913, April 1991). It was recommended that flight times be reduced in order to satisfy Australian Naval hearing conservation regulations (RAN Health Services Manual, 1989), which permit a Permissible Noise Exposure (PNE) of 90 dBA for an 8 hour day.

Permissible Daily Exposure Durations (PDEDs) are calculated using A-weighted Sound Pressure Levels (SPLs) measured at the ear (i.e., A-weighted SPLs at the ear under the helmet).[1] However, in the preliminary study conducted by ARL at-ear SPLs were not measured but estimated using the attenuation value for the ALPHA helmet. The attenuation value is the Sound Level Conversion Factor (SLC_{80}) which represents the degree of attenuation for at least 80% of wearers. The SLC_{80} is subtracted from the C-weighted SPL of the external noise to give the approximate A-weighted SPL of the attenuated noise reaching the operator's ears (see AS 1269 Appendix C, Part 3.2, Notes 1 and 2). In the preliminary study conducted by ARL an SLC_{80} of 13.7 dB was used to estimate at-ear SPLs and associated PDEDs for aircrew in the S-70B-2 (ARL Letter Report M2/913, April 1991). This conversion factor was obtained from a National Acoustic Laboratory (NAL) report on the attenuation characteristics of the ALPHA helmet (NAL, April 1989).

NAL has recently re-examined the attenuation properties of the ALPHA helmet and revised its attenuation rating to 18.0 dB (NAL, August 1991). This revised attenuation rating indicates that the ALPHA helmet provides greater hearing protection than previously reported and that crews could fly sorties of longer duration than previously recommended. The difference between the two SLC_{80} values quoted by NAL for the ALPHA helmet

---

[1] Several frequency weighting curves (A, B and C) are used in human acoustic measurements as they allow for the differential response of the human ear across the whole audio frequency spectrum. The different weighting curves represent the human ear's frequency response at different SPLs — as the SPL of the signal increases, the low frequency response of the ear increases and the appropriate weighting curve moves from A through to C. It is appropriate, for example, to report A-weighted levels (dBA) for acoustic signals with low to moderate SPLs and C-weighted levels (dBC) for signals with high SPLs. However, certain conventions regarding the use of weighting curves have been adopted in the evaluation of hearing protection devices. High freefield ambient SPLs are C-weighted, whilst at-ear SPLs under the protector are A-weighted (even though the at-ear SPL is still high enough to justify the use of the C-weighting curve in most cases). These conventions have been adopted because Australian Standards require that PDEDs be calculated using A-weighted at-ear SPLs, and will be followed in this paper. A and C frequency weighting curves for $^1/_3$ octave bands are included in Appendix C so the reported $^1/_3$ octave measurements can be re-calculated in terms of the other frequency weighting curve if so desired.

does raise some question regarding the reliability of this value. NAL suggested that the difference could be explained in terms of helmet fit with the higher attenuation rating reflecting a better fit between the helmets available for testing and the participating subjects. The SLC_{80} is calculated by averaging the attenuation values in each octave band (for a number of subjects) and subtracting one standard deviation from this average. Thus, better fit for all subjects would result in improved attenuation and reduce the high variability in attenuation associated with large differences in individual helmet fit (both measures contribute to the improved SLC_{80} rating).

ALPHA helmets are individually fitted for aircrew and it is essential that the attenuation characteristics of the ALPHA (and any associated variability resulting from differences in individual fit) be measured using aircrew wearing their own fitted helmets. Furthermore, the SLC_{80} was designed for ease of use and does not take into account the specific noise environment in which the helmet is used.

In summary, the level of hearing protection provided for aircrew in the S-70B-2 by the ALPHA helmet is an issue which requires further investigation. The technique which involves subtracting the attenuation value for the ALPHA helmet (the SLC_{80} rating) from the C-weighted cabin noise has emerged as unsatisfactory because: (a) this technique provides no specific information about the noise environment in the S-70B-2, (b) the SLC_{80} rating for the helmet has yet to be proven reliable, and (c) it has not been measured using aircrew wearing their own fitted helmets.

The first aim of the present study was to resolve this issue by measuring the noise spectrum in the S-70B-2 and the reduction in at-ear SPL provided for aircrew wearing their own fitted helmets in this environment.

1.2 Active Noise Reduction

Aircrew could be provided with additional attenuation devices in order to reduce at-ear SPLs and hence increase their maximum PDED. Additional attenuation could be provided by:

a) passive attenuation devices, such as earplugs, or

b) active attenuation devices, such as Active Noise Reduction (ANR) systems.

Unlike the passive noise attenuation provided by helmets and earplugs, ANR actually cancels some of the noise by generating an acoustic waveform that is (ideally) 180° out of phase with the noise inside the earcup and adding this "anti-noise" to the earcup. The Defence Research Agency (DRA) - Aerospace Division has been developing an ANR system mounted within the earcups of a standard ALPHA MK IV helmet for a number of years. A commercially manufactured ANR headset for general aviation use has been recently released by the BOSE corporation. It is claimed that these systems effectively reduce SPLs within the earcup. An ANR system could well reduce the risk of hearing damage caused by long term exposure to excessive noise.

The second aim of the present study was to assess the performance of two ANR systems (the DRA ANR ALPHA helmet and the BOSE ANR aviation headset) in terms of their ability to reduce at-ear SPLs for aircrew in the S-70B-2.

The above aims were achieved by:

a) measuring cabin noise levels at three crew positions in the S-70B-2 under various flight conditions and using spectral analysis techniques to determine the acoustic characteristics of this noise,

b) measuring at-ear SPLs under the ALPHA helmet and individual variation in the attenuation properties of properly fitted ALPHA helmets,

c) using spectral analysis techniques to determine the acoustic attenuation characteristics of the ALPHA helmet,

d) measuring at-ear SPLs under the BOSE headset and using spectral analysis techniques to determine the acoustic attenuation characteristics of the headset, and

e) measuring the additional attenuation effectively provided by the DRA and BOSE ANR systems and determining the acoustic characteristics of this attenuation.

2. EQUIPMENT AND EXPERIMENTAL PROCEDURE

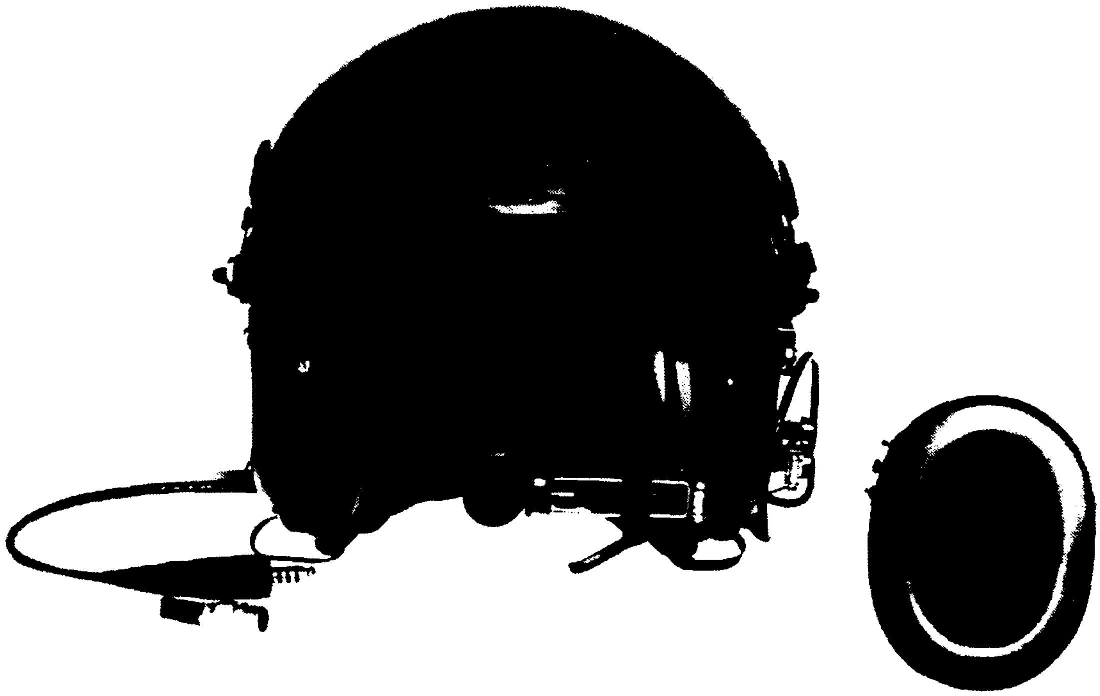
2.1 Helmets and ANR Systems

The equipment assessed consisted of the RAN MK IV ALPHA helmet, the DRA ANR ALPHA helmet [see Figure 1] and the BOSE ANR aviation headset [see Figure 2]. RAN ALPHA helmets were supplied by HS816 Squadron, HMAS Albatross while the Defence Research Agency and BOSE Australia supplied their respective products for evaluation.

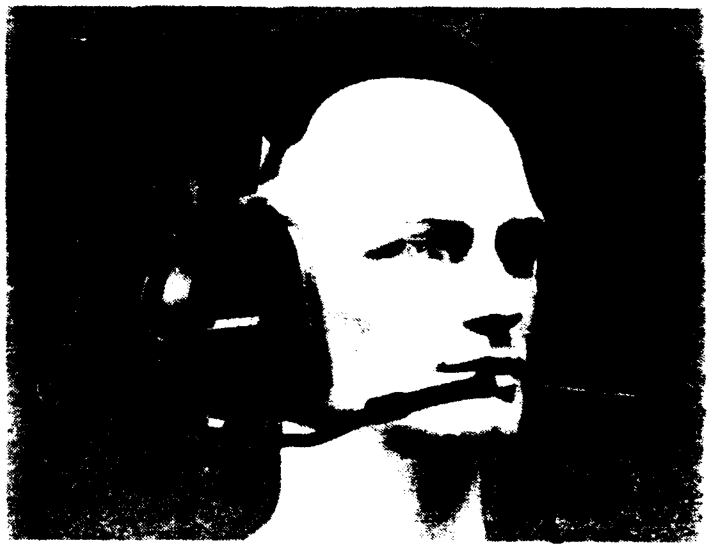
Socket and impedance matching devices were used to ensure that all non-standard helmets and headsets were intercommunication system (ICS) compatible. Each ANR system was powered by a separate power supply which provided independence from the aircraft power supplies. Each system was designed so that in the event of failure it would revert to normal ICS function.

2.2 Aircrew and Aircraft

The Seahawk's primary mission is anti-submarine and anti-surface warfare. In these roles it is operated by a crew of three: Pilot, Tactical Co-ordinator (Tacco) and Sensor Operator (Senso). The Pilot occupies the front right hand seat, the Tacco the front left hand seat and the Senso occupies a position approximately half way down the cabin on the left hand side of the aircraft [see Figure 3]. Another seat is installed at the rear on the right hand side of the aircraft in the Winch Operation position. The Senso or a fourth crew member sits at this position during missions requiring winch operation (e.g., search-and-rescue).

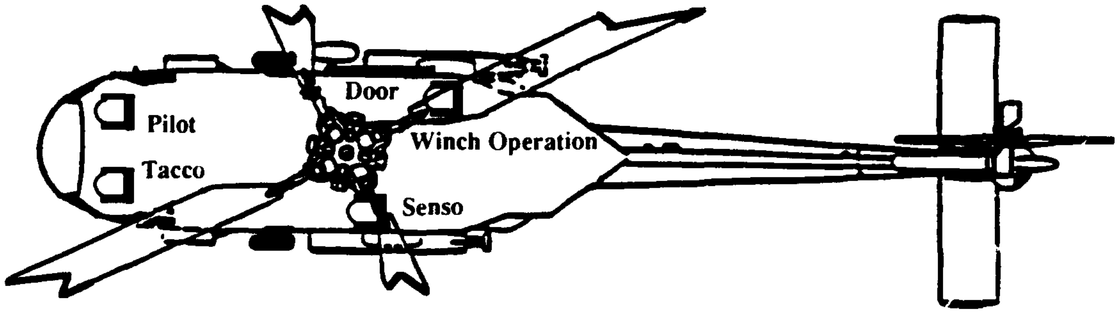


Above: Figure 1. The DRA ANR ALPHA helmet. The ANR system is mounted in a standard earcup.



Right: Figure 2. The BOSE ANR aviation headset.

Below: Figure 3. Crew positions in the S-70B-2.



All subjects were members of the Seahawk Introduction and Transition Unit based at NAS Nowra. Measurements were made aboard an S-70B-2 as part of Development, Test and Evaluation trials on flights from RAAF EAST SALE and NAS NOWRA. All measurements were made at an altitude of approximately 33 metres above sea-level and with a mean sea-level barometric pressure of 1015.6 hectopascals.

2.3 Recording and Measurement System

Cabin noise levels and noise levels within the earcup were recorded simultaneously using two Knowles BT1759 electret microphones. One microphone was mounted on the outside of the helmet directly opposite the ear canal whilst the second was mounted within the earcup (placed towards the front of the shell to avoid occlusion of the ear). The microphones had a flat frequency response (±2 dB) from 50 Hz to 7 kHz and were powered by a small independent 3 V power supply. The microphone outputs were connected to a portable Sony TCD-D10PROII digital audio tape recorder with a sampling frequency of 44.1 kHz and flat frequency response between 20 Hz and 22 kHz (±1dB). The microphone outside the helmet was connected to the right channel microphone input and the microphone within the earcup connected to the left channel microphone input. Each channel was calibrated using a Bruel and Kjaer 4230 sound level calibrator.

2.4 Analysis Equipment

Recordings were analysed post-flight using a Bruel and Kjaer 2064 dual channel spectral analyser. Third octave band analyses were performed to determine the acoustic characteristics of:

a) the noise in the S-70B-2,

b) the attenuation properties of the ALPHA helmet and the BOSE headset, and

c) the attenuation properties of the DRA and BOSE ANR systems.

2.5 Test Procedure

Measurements were made at the Tacco, Senso and Winch Operation positions. However, the flight time available for the trials was limited and the testing procedure was varied for the different headsets in order to achieve the experimental aims in the shortest possible time.

DRA ANR ALPHA Helmet

Although DRA supplied three ALPHA ANR helmets of different sizes, aircrew availability meant that only one helmet could be adjusted to provide a satisfactory fit for one member of the crew. This crew member moved to different positions in the aircraft when measurements were made. Whilst this procedure was quite time consuming and involved landing in order to move in and out of the Tacco position, a correct helmet fit

was considered essential in order to collect accurate data on the ALPHA MK IV helmet[2] and the DRA ANR system.

Measurements were made on the DRA ANR ALPHA helmet at the Tacco, Senso and Winch Operation positions in the following flight conditions:

a) Transition (from hover to cruise),

b) Cruise (125 kts),

c) Deceleration (from cruise to hover),

d) Hover with Door Shut, and

e) Hover with Door Open.

Cabin spectra and spectra within the earcup were simultaneously recorded for 30 seconds with ANR off and then recorded for 30 seconds with ANR on in each measurement condition.

RAN MK IV ALPHA Helmet

Measurements were also made at the Senso position in the Hover, Door Shut condition using six volunteer aircrew wearing their own ALPHA MK IV helmets in order to provide an estimate of the variance associated with the attenuation characteristics of properly fitted helmets. At-ear SPLs measured using the DRA ANR ALPHA helmet were conservatively adjusted to compensate for these individual differences. The adjusted at-ear SPLs are conservative figures in that they indicate the maximum at-ear SPL that would be measured for at least 84% of aircrew wearing fitted ALPHA helmets.

BOSE ANR Headset

The BOSE ANR headset is designed to be universally adjustable. This headset was passed to different crew members occupying different positions in the aircraft when measurements were made. The BOSE headset was evaluated at the Tacco, Senso and Winch Operation positions in the:

a) Cruise, and

b) Hover, Door Shut conditions.

Cabin spectra and spectra within the earcup were again simultaneously recorded for 30 seconds with ANR off and then recorded for 30 seconds with ANR on in each measurement condition.

---

[2]DRA reports that the ANR ALPHA helmet with ANR off has the same attenuation characteristics as the standard ALPHA MK IV helmet (Rood and Lucas, 1985). Additional measurements made during the present trials confirm this report. Thus, the DRA ANR helmet with ANR off provides accurate data regarding the attenuation characteristics of the standard RAN ALPHA MK IV helmet.

3. RESULTS

3.1 Ambient Noise Levels in the S-70B-2

Table 1 shows the ambient cabin noise levels (dBC re 20 μPa) measured at each of the three crew positions in each flight condition.

	Tacco	Senso	Winch Operation
Transition	103 dBC	107 dBC	107 dBC
Cruise	107 dBC	109 dBC	106 dBC
Deceleration	105 dBC	107 dBC	106 dBC
Hover, Door Shut	103 dBC	108 dBC	105 dBC
Hover, Door Open	109 dBC	110 dBC	114 dBC

Table 1. Ambient cabin SPLs (dBC re 20 μPa) measured at each of the three crew positions in each flight condition.

As Table 1 indicates, high ambient noise levels occur in the cabin of the S-70B-2 under normal flight conditions.

3.1.1 Acoustic Characteristics of the Cabin Noise in the S-70B-2

Third octave band analyses were performed on the recordings in order to determine the acoustic characteristics of the cabin noise in the S-70B-2. Figures 4, 5 and 6 show $^1/_3$ octave analyses of the cabin noise measured at the Tacco, Senso and Winch Operation positions in each flight condition.

High noise levels (> 90dBC) occurred in $^1/_3$ octave bands centered between 31.5 and 5000 Hz at the Senso and Winch Operation positions [see Figures 5 and 6]. Spectral analysis reveals that the highest noise levels (> 100 dBC) generated at these positions occurred in $^1/_3$ octave bands centered between 1600 and 2500 Hz.

At the Tacco position, noise levels in bands centered between 125 and 5000 Hz were generally lower than those measured at the Senso and Winch Operation positions. Noise levels at the Tacco position tended to be highest in bands centered between 31.5 and 100 Hz [see Figure 4]. The levels in these bands were comparable those measured at the Senso and Winch Operation positions.

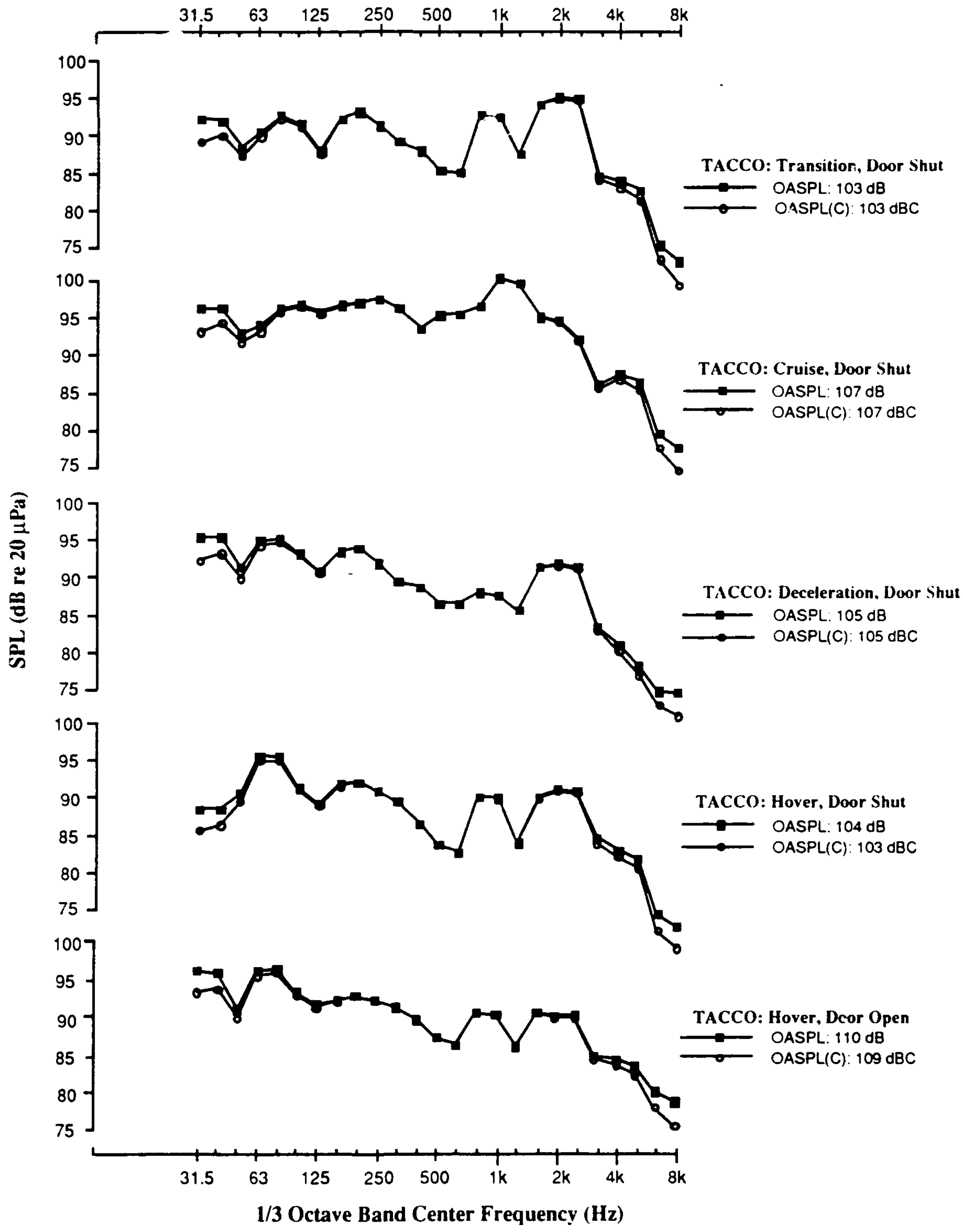


Figure 4. Third octave analyses of the cabin noise measured at the Tacco position in the Transition, Door Shut; Cruise, Door Shut; Deceleration, Door Shut; Hover, Door Shut and Hover, Door Open flight conditions. Also shown are unweighted and C-weighted overall sound pressure levels (OASPL).

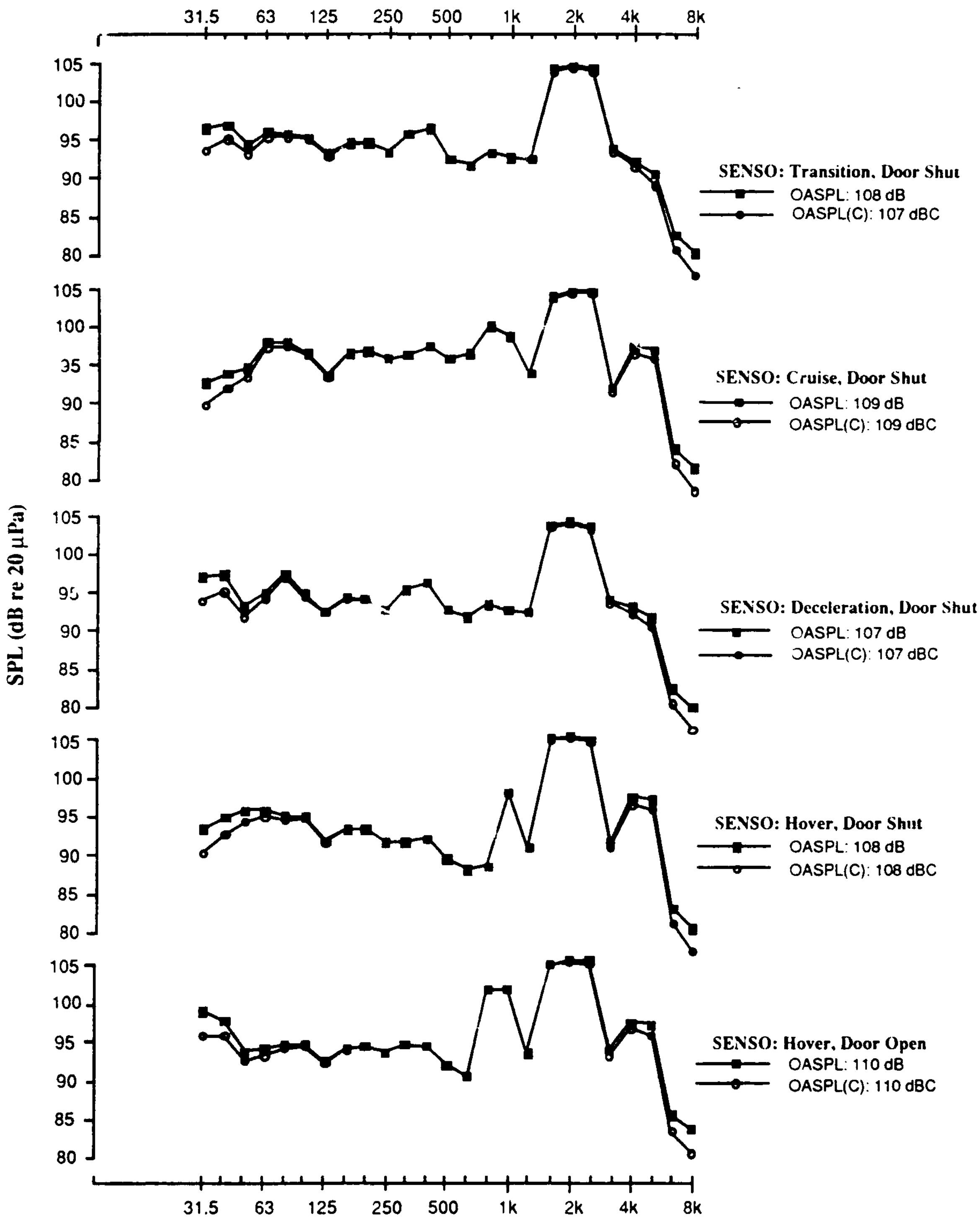


Figure 5. Third octave analyses of the cabin noise measured at the Senso position in the Transition, Door Shut; Cruise, Door Shut; Deceleration, Door Shut; Hover, Door Shut and Hover, Door Open flight conditions. Also shown are unweighted and C-weighted overall sound pressure levels (OASPL).

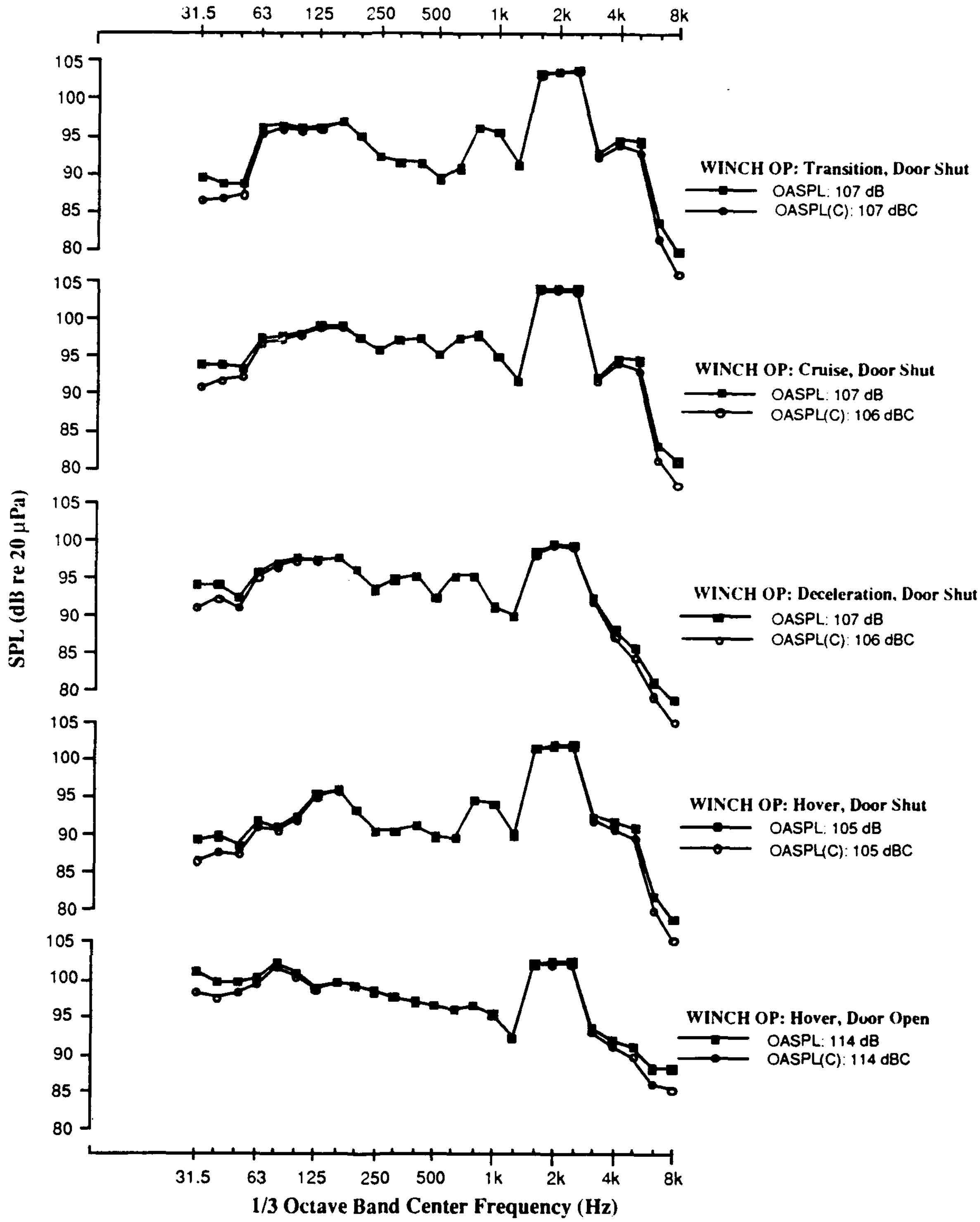


Figure 6. Third octave analyses of the cabin noise measured at the Winch Operation position in the Transition, Door Shut; Cruise, Door Shut; Deceleration, Door Shut; Hover, Door Shut and Hover, Door Open flight conditions. Also shown are unweighted and C-weighted overall sound pressure levels (OASPL).

3.2 Attenuation Characteristics of the ALPHA Helmet

3.2.1 At-Ear SPLs

Table 2 shows the at-ear SPLs (dBA re 20 µPa) measured in the earcup of the DRA ANR ALPHA helmet (with ANR off) at each of the three crew positions in each flight condition. Measurements made at the Senso position using six volunteer aircrew wearing their own fitted helmets revealed that the ALPHA helmet provided a mean attenuation of 25.28 dB with an associated standard deviation of 3.33 dB in the Hover, Door Open flight condition. Measured at-ear SPLs were adjusted by adding 4.00 dB in order to compensate for the variability in the attenuation properties of the ALPHA helmet that results from individual differences in helmet fit.

	Tacco	Senso	Winch Operation
Transition			
At-Ear SPL	77 dBA	83 dBA	84 dBA
Adjusted At-Ear SPL	81 dBA	87 dBA	88 dBA
Cruise			
At-Ear SPL	86 dBA	84 dBA	85 dBA
Adjusted At-Ear SPL	90 dBA	88 dBA	89 dBA
Deceleration			
At-Ear SPL	78 dBA	83 dBA	85 dBA
Adjusted At-Ear SPL	82 dBA	87 dBA	89 dBA
Hover, Door Shut			
At-Ear SPL	77 dBA	82 dBA	83 dBA
Adjusted At-Ear SPL	81 dBA	86 dBA	87 dBA
Hover, Door Open			
At-Ear SPL	78 dBA	83 dBA	84 dBA
Adjusted At-Ear SPL	82 dBA	87 dBA	88 dBA

Table 2. At-ear SPLs (dBA re 20 µPa) measured at each of the three crew positions in each flight condition with the DRA ANR ALPHA helmet. Also shown is the adjusted at-ear SPL which is a conservative figure allowing for variability in the attenuation properties of ALPHA helmets.

3.2.2 Frequencies Attenuated by the ALPHA Helmet

Third octave band analyses were also performed in order to determine frequencies effectively attenuated by the ALPHA helmet. Attenuation was defined as the difference between noise levels measured outside the helmet and the noise levels measured in the earcup. Little variation in the attenuation properties of the helmet occurred with changes in measurement position or flight condition (i.e., the system is linear) and hence the mean attenuation provided by the ALPHA helmet in each 1/3 octave band is reported [see Figure 7]. The mean attenuation value was calculated by averaging attenuation for each 1/3 octave band across all crew positions and flight conditions.

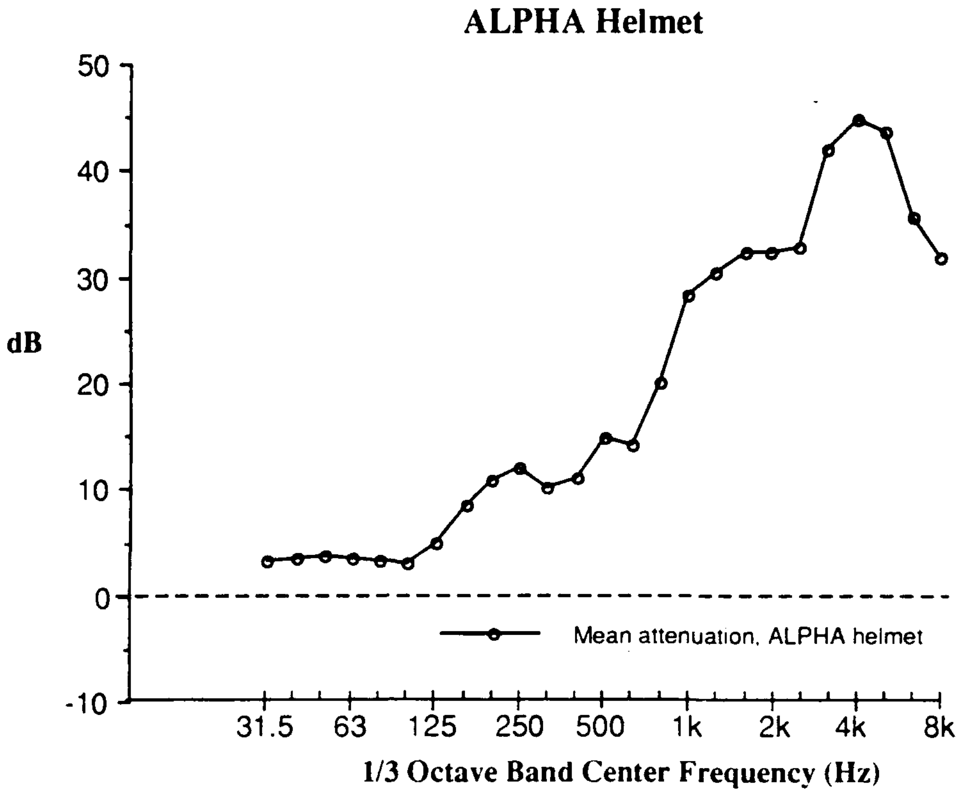


Figure 7. Attenuation provided by the ALPHA helmet in each 1/3 octave frequency band.

The ALPHA helmet provides good attenuation (> 20 dB) in 1/3 octave bands centered between 800 Hz and 8 kHz, and some attenuation (around 10 dB to 15 dB) in bands centered between 160 and 630 Hz. The ALPHA helmet provides little attenuation at low frequencies, particularly in 1/3 octave bands centered between 31.5 Hz and 125 Hz.

3.3 Effectiveness of the DRA ANR System

3.3.1 At-Ear SPLs

Table 3 shows the at-ear SPLs (dBA re 20 μPa) measured in the earcup of the DRA ANR ALPHA helmet (with ANR on) at each of the three crew positions in each flight condition. The improvement in attenuation with ANR on (dB) is also shown. Measured at-ear SPLs with ANR on were again adjusted by adding 4.00 dB in order to produce a conservative figure which allows for variability in the attenuation characteristics of the ALPHA resulting from individual differences in helmet fit.

	Tacco	Senso	Winch Operation
Transition			
At-Ear SPL	72 dBA	78 dBA	78 dBA
ANR Attenuation	5 dB	5 dB	6 dB
Adjusted At-Ear SPL	76 dBA	82 dBA	82 dBA
Cruise			
At-Ear SPL	79 dBA	80 dBA	75 dBA
ANR Attenuation	7 dB	4 dB	10 dB
Adjusted At-Ear SPL	83 dBA	84 dBA	79 dBA
Deceleration			
At-Ear SPL	74 dBA	78 dBA	77 dBA
ANR Attenuation	4 dB	5 dB	8 dB
Adjusted At-Ear SPL	78 dBA	82 dBA	81 dBA
Hover, Door Shut			
At-Ear SPL	72 dBA	80 dBA	76 dBA
ANR Attenuation	5 dB	2 dB	7 dB
Adjusted At-Ear SPL	76 dBA	84 dBA	80 dBA
Hover, Door Open			
At-Ear SPL	74 dBA	78 dBA	79 dBA
ANR Attenuation	4 dB	5 dB	5 dB
Adjusted At-Ear SPL	78 dBA	82 dBA	83 dBA

Table 3. At-ear SPLs (dBA re 20 μPa) measured at each of the three crew positions in each flight condition with the DRA ANR system on. Also shown is the additional attenuation provided by ANR and the adjusted at-ear SPL which is a conservative figure allowing for variability in the attenuation properties of ALPHA helmets.

The DRA ANR system does effectively reduce at-ear SPLs. The mean additional attenuation produced by ANR was 5.5 dB. This mean value was calculated by averaging the additional attenuation produced by ANR across all crew positions and flight conditions.

3.3.2 Frequencies Attenuated by the DRA ANR System

Third octave band analysis was also used to determine frequencies attenuated by the DRA ANR system. Attenuation was defined as the difference between noise levels measured in the earcup with ANR on and ANR off. Once again, little variation in the attenuation properties of the helmet occurred with changes in measurement position or flight condition and the mean attenuation provided by the DRA ANR system in each $^1/_3$ octave frequency band is reported [see Figure 8]. The mean attenuation value was calculated by averaging attenuation for each $^1/_3$ octave band across all crew positions and flight conditions. These data are compared with the attenuation provided by the ALPHA helmet in order to show the frequencies additionally attenuated when ANR was on.

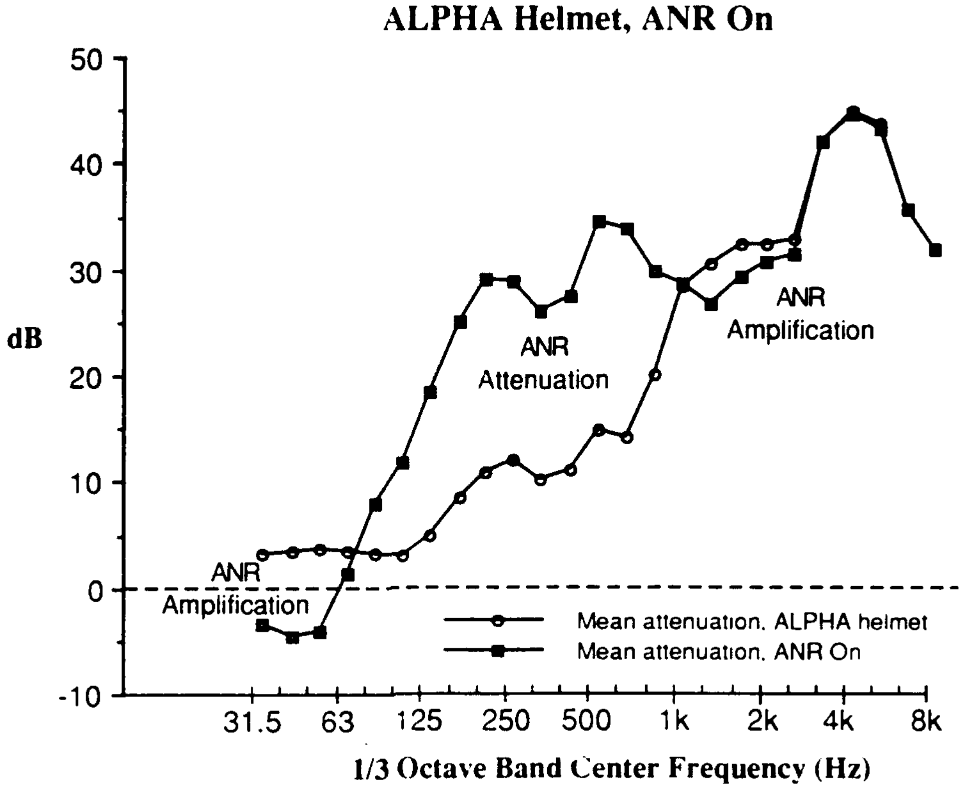


Figure 8. Passive attenuation provided by the ALPHA helmet in each 1/3 octave frequency band. These data are compared with the attenuation provided by the ALPHA helmet with ANR On, in order to show the effectiveness of the ANR system.

The DRA ANR system substantially reduced the noise levels in 1/3 octave bands centered between 80 and 800 Hz, although some amplification is apparent in the bands centered between 31.5 and 63 Hz and 1250 and 2500 Hz when ANR was on.

Figures showing at-ear SPLs and the 1/3 octave attenuation provided by the ALPHA helmet and DRA ANR system for each crew position and flight condition are included in Appendix A.

3.4 Attenuation Characteristics of the BOSE Headset and ANR System

3.4.1 At-Ear SPLs

Table 4 shows the at-ear SPLs (dBA re 20 μPa) measured in the earcup of the BOSE ANR headset (with ANR off) at each of the three crew positions in two flight conditions (Hover, Door Shut and Cruise, Door Shut). Comparison of the at-ear SPLs measured at these crew positions and flight conditions reveals that the BOSE headset generally provides greater passive attenuation than the ALPHA helmet (a mean improvement in attenuation of 2 dB averaged across the three crew positions and two flight conditions).

Adjusted at-ear SPLs are not presented in Table 4 as it was not possible to determine the variance in the attenuation provided by the BOSE headset resulting from individual

differences in headset fit from the present measurements. Measurements for different crew members were not repeated for any one crew position and flight condition.

	Tacco	Senso	Winch Operation
Cruise			
At-Ear SPL (ANR Off)	81 dBA	83 dBA	84 dBA
At-Ear SPL (ANR On)	76 dBA	77 dBA	79 dBA
ANR Attenuation	5 dB	6 dB	5 dB
Hover, Door Shut			
At-Ear SPL (ANR Off)	75 dBA	83 dBA	79 dBA
At-Ear SPL (ANR On)	69 dBA	78 dBA	73 dBA
ANR Attenuation	6 dB	5 dB	6 dB

Table 4. At-ear SPLs (dBA re 20 μPa) measured at each of the three crew positions in two flight conditions with the BOSE headset with ANR Off and ANR On. Also shown is the additional attenuation provided by ANR.

At-ear SPLs measured in the earcup with ANR on are shown in Table 4. The improvement in attenuation associated with ANR (dB) is also shown. The mean additional attenuation provided by the BOSE ANR system was 5.5 dB. This mean value was calculated by averaging the additional attenuation produced by ANR across all crew positions and flight conditions.

3.4.2 Frequencies Attenuated by the BOSE Headset and ANR System

The mean attenuation provided by the BOSE headset in each $^1/_3$ octave frequency band is shown in Figure 9. The mean attenuation value was calculated by averaging the attenuation for each $^1/_3$ octave band across the three measurement positions and two flight conditions.

The BOSE headset (with ANR off) provides good attenuation (> 20 dB) in $^1/_3$ octave bands centered between 630 Hz and 8kHz, and some attenuation (around 10 dB to 15 dB) in bands centered between 200 and 500 Hz. Very little attenuation is provided in low frequency $^1/_3$ octave bands, centered from 31.5 to 160 Hz.

The BOSE ANR system substantially reduced the noise levels in $^1/_3$ octave bands centered between 31.5 and 500 Hz, with ANR producing slight amplification in $^1/_3$ octave bands centered between 800 and 1250 Hz.

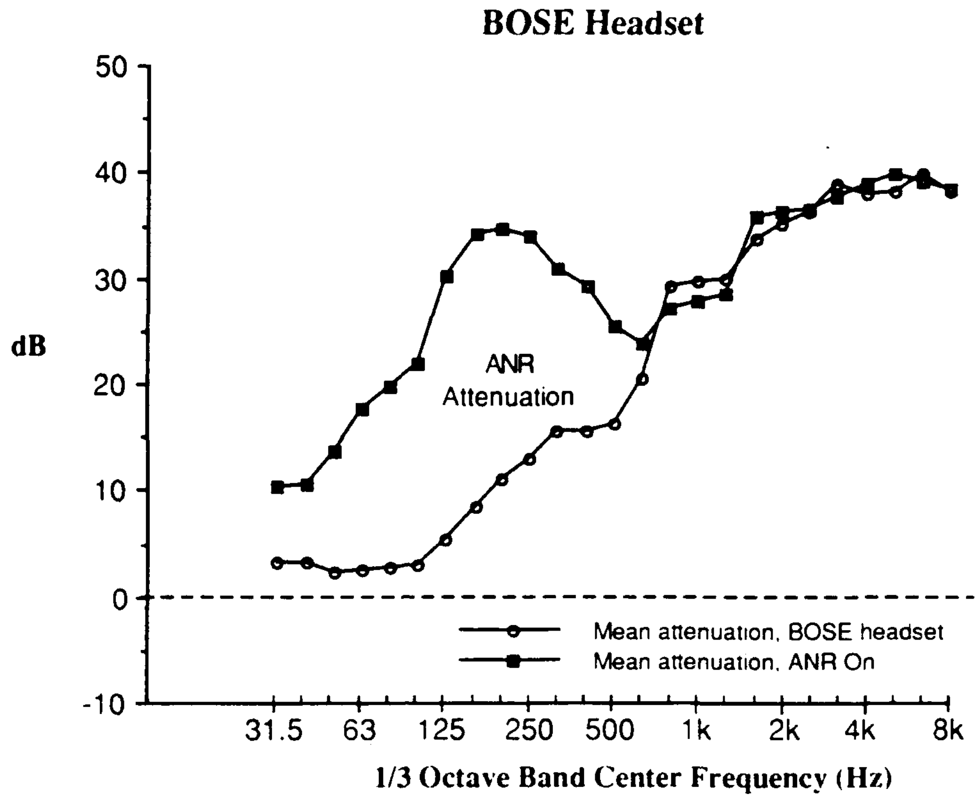


Figure 9. Attenuation provided by the BOSE headset in each 1/3 octave frequency band with ANR Off and ANR On.

Figures showing at-ear SPLs and the 1/3 octave attenuation provided by the BOSE headset and ANR system in each crew position and flight condition are included in Appendix B.

4. DISCUSSION

High cabin noise levels occur in the S-70B-2 under normal flight conditions, with ambient cabin noise levels often exceeding 105 dBC, particularly at the Senso and Winch Operation positions [see Table 1]. High noise levels occurred in the 31.5-5000 Hz frequency region at the Senso and Winch Operation positions, with a consistent high energy "peak" present in the 1600-2500 Hz frequency region. Noise levels at the Tacco position were generally lower than those measured at the Senso and Winch Operation positions in the 125-5000 Hz frequency region, with noise tending to peak in the 31.5-100 Hz frequency region at this position. Noise levels in this low frequency region were similar to those measured at the Senso and Winch Operation positions, however [see Section 3.1.1].

High noise levels are aerodynamically and mechanically generated in the S-70B-2. Rotor noise produces a high energy peak at 17 Hz with harmonically related repetitions occurring at 34, 51, 68 and 85 Hz. Other shaft-related noise produces prominent peaks at 80 and 96 Hz. The gearbox has a main (planetary) meshing frequency of 980 Hz with

relatively high energy also being produced in the first two harmonic peaks (1960 and 2940 Hz). The main bevel mesh produces an additional high energy peak at 2012 Hz.

While the auditory environment in the S-70B-2 results from a complex acoustic interaction, it seems that aerodynamic noise is produced predominantly at lower frequencies (below 100 Hz) and similar levels at the three crew positions. Mechanical noise is produced predominantly at higher frequencies (above 980 Hz) and higher levels at the Senso and Winch Operation positions.

The ALPHA helmet has good passive attenuation properties and serves to reduce the cabin noise level considerably before it reaches the ear [see Table 2]. Current hearing conservation guidelines recommend a PNE of 90 dBA for an 8 hour day (RAN Health Services Manual, 1989). At-ear SPLs measured under the ALPHA helmet at the Tacco, Senso and Winch Operation positions fall well within this limit, indicating that aircrew could fly for at least 8 hours without exceeding this recommended PNE. Measurements made on aircrew wearing their own fitted helmets show that some variability in the attenuation characteristics of the ALPHA does occur for individual users. However, this variation is small and it is estimated that at-ear SPLs for at least 84% of aircrew would fall within +3.33 dBA of those measured at each crew position [see Section 3.2.1]. At-ear SPLs which have been conservatively adjusted to compensate for this variability still fall within the recommended PNE of 90 dBA for an 8 hour day [see Table 2].

The Surgeon-General of the Australian Defence Force (SGADF) has produced a draft document which proposes a reduction in the PNE limit from 90 dBA to 85 dBA for an 8 hour day (SGADF 1698/1990). Should this lower limit be adopted, aircrew would exceed this level if flying in excess of 3-4 hours per day. Aircrew sitting at the Winch Operation position, for example, could only fly for 3 hours 10 minutes (based on adjusted at-ear SPL for cruise flight, see Table 2) before a PNE limit of 85 dBA would be exceeded. Aircrew would have to be provided with additional noise attenuation devices in order to maintain reasonable manning levels for operational flying if a PNE of 85 dBA is introduced.

The ALPHA helmet adequately attenuates high frequency noise, but provides limited attenuation at frequencies below 800 Hz and virtually no attenuation at frequencies below 160 Hz [see Section 3.2.2]. This is a problem in the S-70B-2 as high noise levels are generated at frequencies below 800 Hz. Attenuating this low frequency noise would produce the most benefit in terms of reducing SPLs at the ear under the ALPHA helmet.

It is possible to attenuate this low frequency noise using ANR technology. Both the DRA and the BOSE ANR systems attenuated noise in this frequency region and effectively reduced at-ear SPLs by a further 5.5 dB [see Sections 3.3.1 and 3.4.1]. Either ANR system incorporated into the S-70B-2 would provide sufficient attenuation to allow compliance with a PNE limit of 85 dBA. At-ear SPLs measured under the DRA ALPHA helmet with ANR on (which have been adjusted to compensate for any variability in the attenuation characteristics of the ALPHA) also fall within this limit [see Table 3].

In terms of noise attenuation, the BOSE headset is more effective than the DRA ANR ALPHA helmet in two ways. Firstly, the passive attenuation characteristics of the BOSE headset are better than those of the ALPHA helmet. The headset (with ANR off) reduces at-ear noise levels by 2 dB more than the ALPHA helmet (with ANR off) on average [see Tables 2 and 4]. The double silicone-filled earcup seals provided by BOSE effectively seal the headset to the head resulting in reduced at-ear noise. It was not possible to determine the variance in the attenuation properties of the BOSE headset associated with individual differences in headset fit from the present measurements. However, this variability would certainly be no more than that measured for the ALPHA helmet (3.33 dB) as the BOSE headset is universally adjustable and less susceptible to variation in attenuation resulting from fit differences. Thus, it would be expected that conservatively adjusted at-ear SPLs for the BOSE would be at least 2 dB lower than those calculated for the ALPHA helmet.

Secondly, the BOSE ANR headset with ANR on provides additional attenuation at all frequencies. The headset itself provides adequate passive attenuation at frequencies above 630 Hz while the BOSE ANR system attenuates all lower frequencies [see Figure 9]. The DRA ANR ALPHA helmet, on the other hand, does not provide additional attenuation at all frequencies with ANR on. The ALPHA helmet provides adequate passive attenuation at frequencies above 800 Hz and the DRA ANR system provides additional attenuation between 63 and 800 Hz. However, the DRA ANR system amplifies the noise that occurs in the frequency region below 63 Hz [see Figure 8].[3]

On the other hand, the DRA ANR ALPHA helmet offers a major advantage when current military requirements are considered. Aircrew wear impact resistant helmets approved for military use (such as the ALPHA) rather than headsets. The DRA ANR system has been incorporated inside the earcups of a standard ALPHA helmet and is superior to the BOSE in this sense. The BOSE headset could not be mounted within the ALPHA helmet as the earcups containing the ANR circuitry are quite large. If the BOSE ANR headset were to be used in the S-70B-2 it would have to be incorporated into an approved helmet with a suitable amount of space available.

In summary, both the DRA ANR ALPHA helmet and the BOSE ANR headset effectively reduce at-ear SPLs and would allow aircrew to maintain realistic flight duration times should a recommended PNE limit of 85 dBA be adopted. The BOSE ANR headset has better attenuation characteristics, but would have to be incorporated into an approved helmet in order to be used in the S-70B-2. The DRA ANR ALPHA helmet offers adequate performance and would require no further development to be used in the S-70B-2. However, the passive attenuation characteristics of the ALPHA helmet could be

[3]Both ANR systems amplify some higher frequency noise. The DRA ANR system amplifies noise in the 1250 - 2500 Hz frequency region and the BOSE ANR system amplifies noise in the 800 - 1250 Hz frequency region. However, this amplification is slight and occurs at frequencies where the respective helmet or headset provides adequate passive attenuation [see Sections 3.3.2 and 3.4.2].

further improved by fitting double silicone-filled earcup seals of the BOSE design. The attenuation afforded by the DRA ANR system could also be further improved by modifying the attenuation bandwidth so that ANR attenuated frequencies below 63 Hz.

Crews wearing standard ALPHA helmets could use passive devices such as earplugs to provide additional attenuation and reduce at-ear SPLs. However, an ANR system offers two advantages over the use of earplugs. Firstly, earplugs such as the EAR ear defender provide no attenuation at frequencies below 125 Hz. Noise levels at these frequencies are high in the S-70B-2 and can be effectively attenuated by an efficient ANR system. Secondly, earplugs would degrade ICS intelligibility, whereas ANR will improve intelligibility as it reduces noise levels at the frequencies which mask speech. While the effects of ANR on speech intelligibility in the S-70B-2 have not been empirically investigated, there is clearly a subjective improvement in ICS intelligibility when ANR is on. Improved voice communication could improve aircrew performance by decreasing errors associated with passing information over the ICS.

5. CONCLUSION

The standard RAN ALPHA helmet has good attenuation properties which allow current hearing conservation guidelines (recommending a PNE of 90 dBA for an 8 hour day) to be met. Should a proposed PNE of 85 dBA be adopted, aircrew will require additional attenuation devices to allow realistic flight times to be maintained. In this case, aircrew would:

a) have to be supplied with helmets incorporating ANR technology (which potentially benefits ICS intelligibility), or

b) wear earplugs (such as the EAR ear defender) under the standard RAN ALPHA helmet (and suffer a decrease in ICS intelligibility).

ANR effectively reduces at-ear SPLs by attenuating the high levels of low frequency noise produced in the Seahawk. An additional advantage of ANR is a potential improvement in ICS intelligibility, although further investigation is required to confirm this issue. Present results indicate that a helmet mounted ANR system would produce greater efficiency in the system by allowing realistic flight durations to be maintained, improving communication, and reducing fatigue.

Acknowledgements

The authors gratefully acknowledge the comments made by Dr J. Manton, Mr B. Rebbechi and Dr B. Clark during the preparation of this report.

REFERENCES

Aeronautical Research Laboratory (1991, April). Sound Levels for the Tacco and Senso in the S-70B-2. Letter Report M2/913. Melbourne, Australia.

Australian Standard 1269-1989, (1989). Acoustics-Hearing Conservation. Standards Association of Australia, Sydney, Australia.

National Acoustic Laboratory, (1989, April). Attenuation Characteristics of the ALPHA. Unpublished Report, Sydney, Australia.

National Acoustic Laboratory, (1991, August). Attenuation Characteristics of the ALPHA. Unpublished Report, Sydney, Australia.

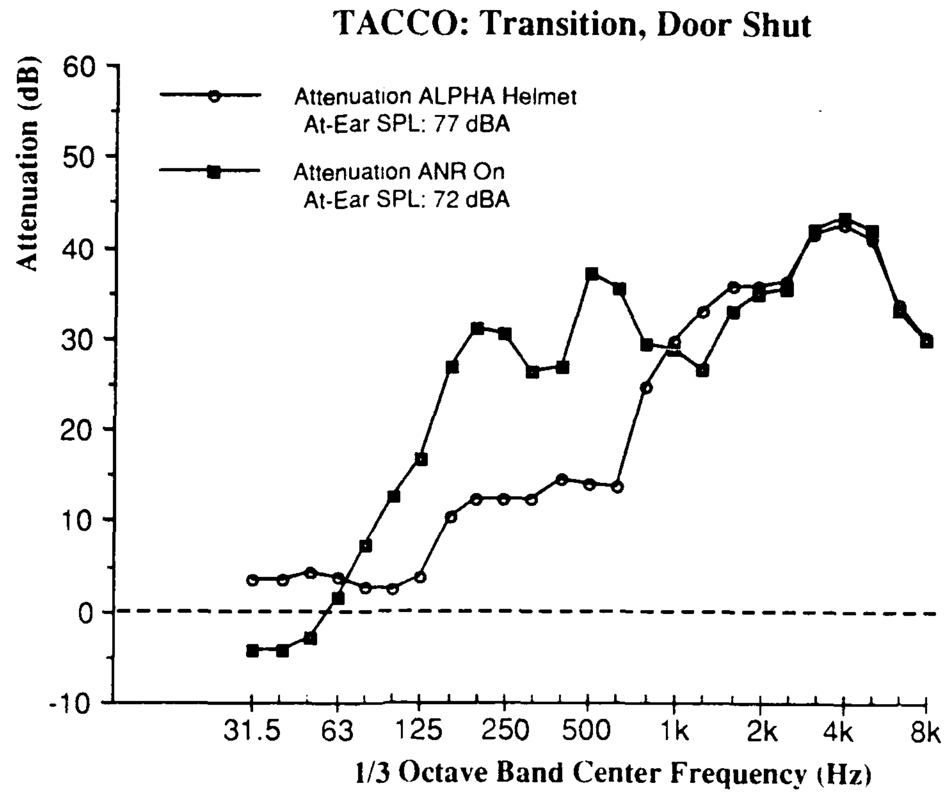
RAN Health Services Manual, (1989). Vol. 2, Chapter 56, Australian Book of Reference, 1991. Department of Defence, Canberra, Australia.

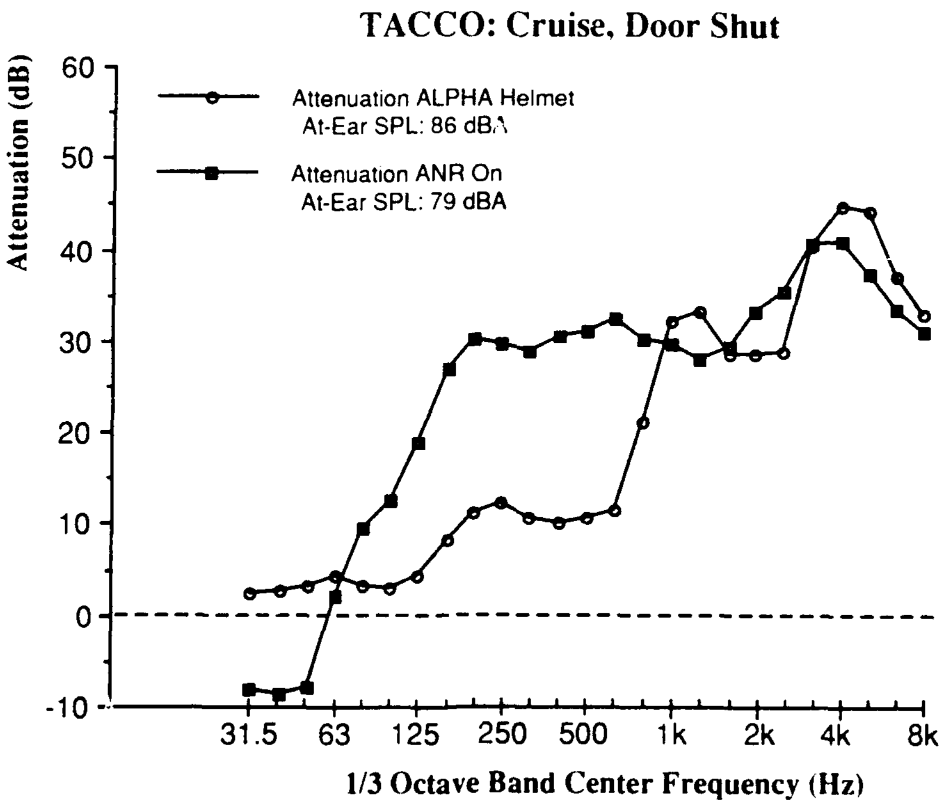
Rood, G.S. and Lucas, S.H., (1985). Evaluation of an Active Noise Reduction System for the MK IV Flying Helmet During Laboratory and Helicopter Trials. Technical Report 85035. Royal Aircraft Establishment, Farnborough, England.

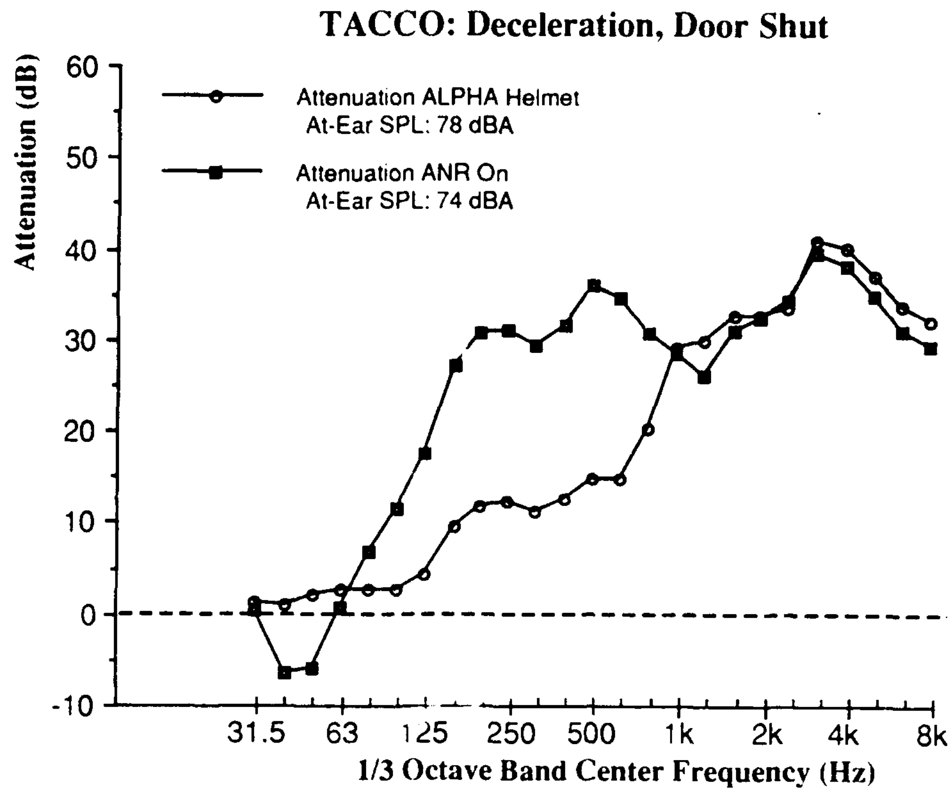
Surgeon-General of the Australian Defence Force, (1990). Hearing in the Australian Defence Force. Draft DI(G), SGADF 1698/1990. Canberra, Australia.

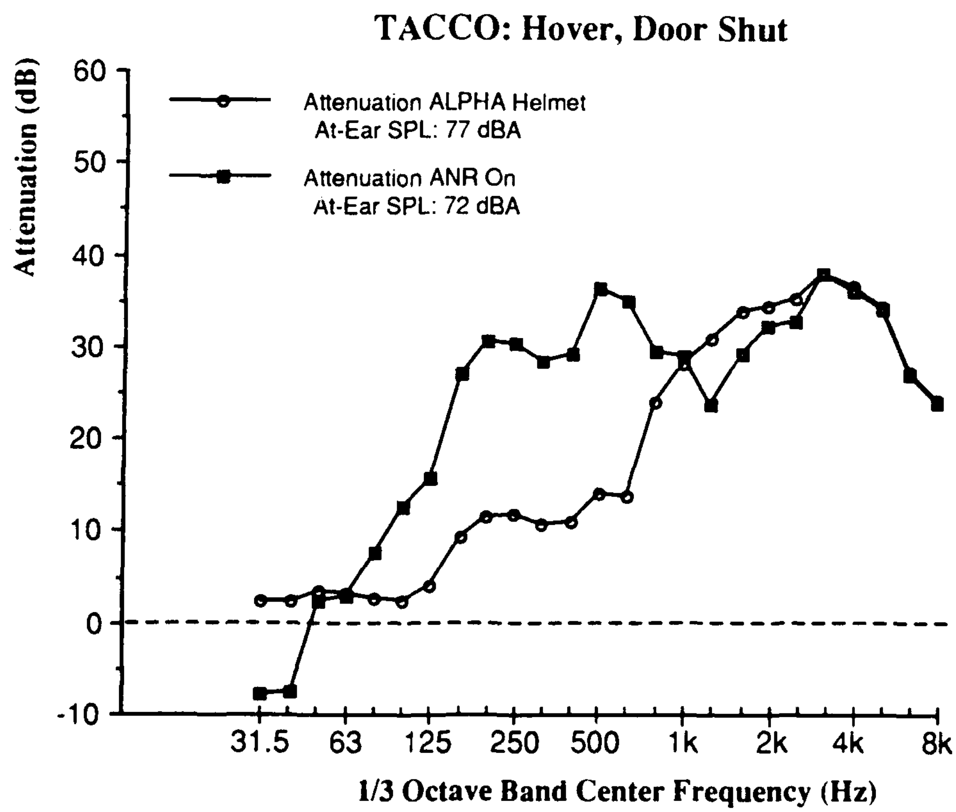
APPENDIX A

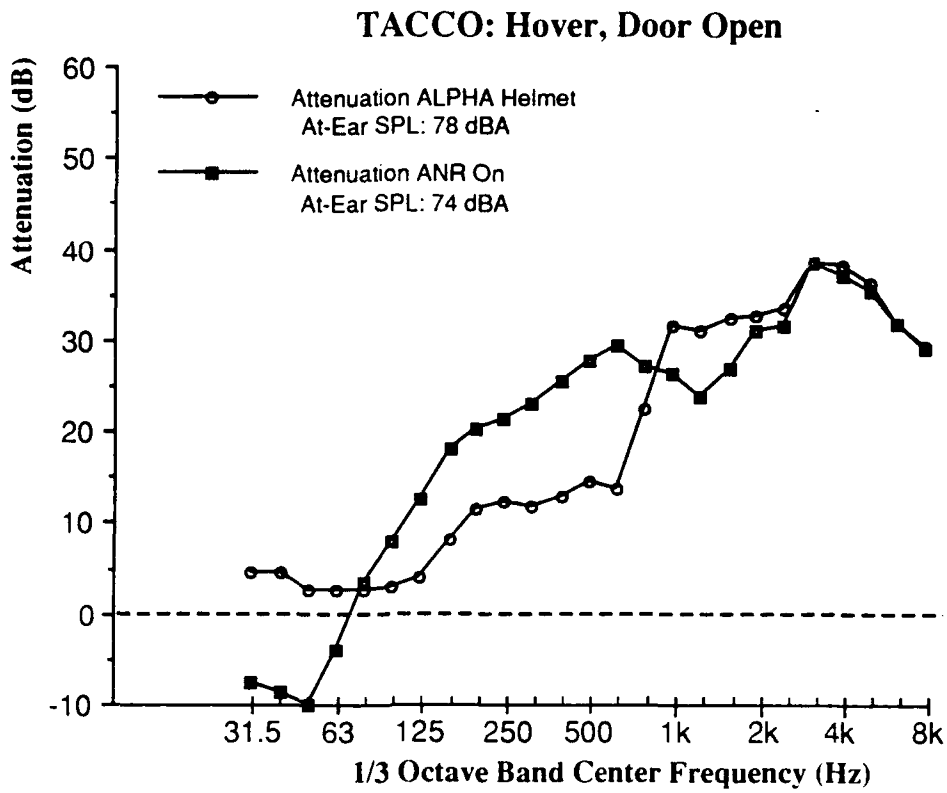
Attenuation provided by the ALPHA helmet and DRA ANR system for each crew position and flight condition


TACCO: Transition, Door Shut
Attenuation ALPHA Helmet
At-Ear SPL: 77 dBA
Attenuation ANR On
At-Ear SPL: 72 dBA
Attenuation (dB)
60
50
40
30
20
10
0
-10
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)

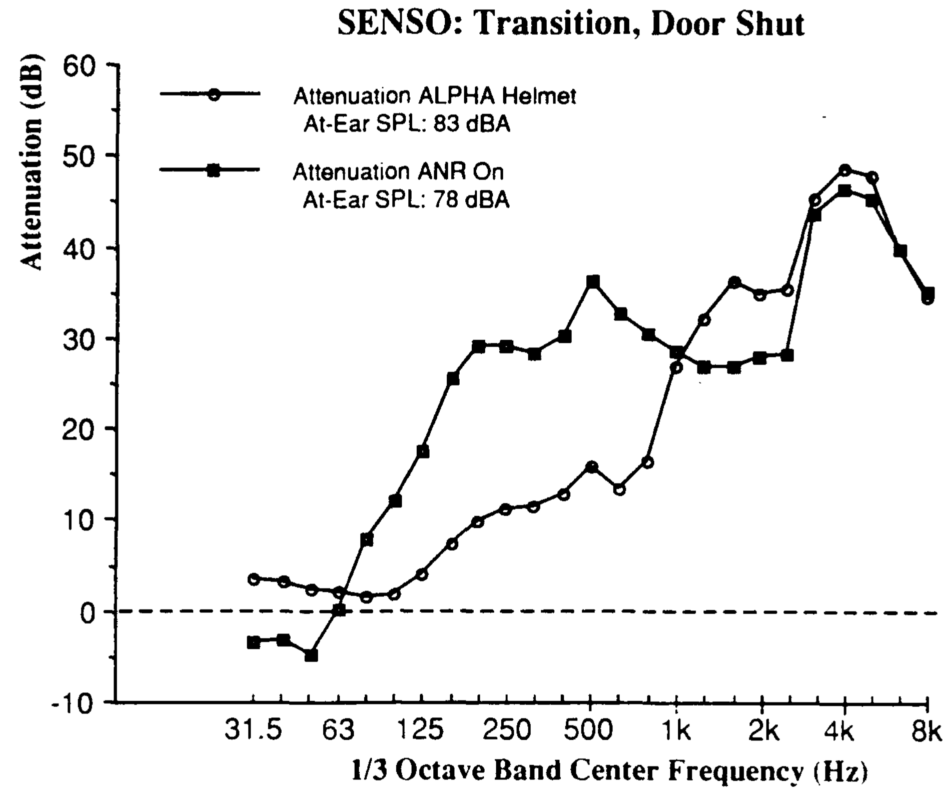

TACCO: Cruise, Door Shut
Attenuation ALPHA Helmet
At-Ear SPL: 86 dBA
Attenuation ANR On
At-Ear SPL: 79 dBA
Attenuation (dB)
60
50
40
30
20
10
0
-10
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)

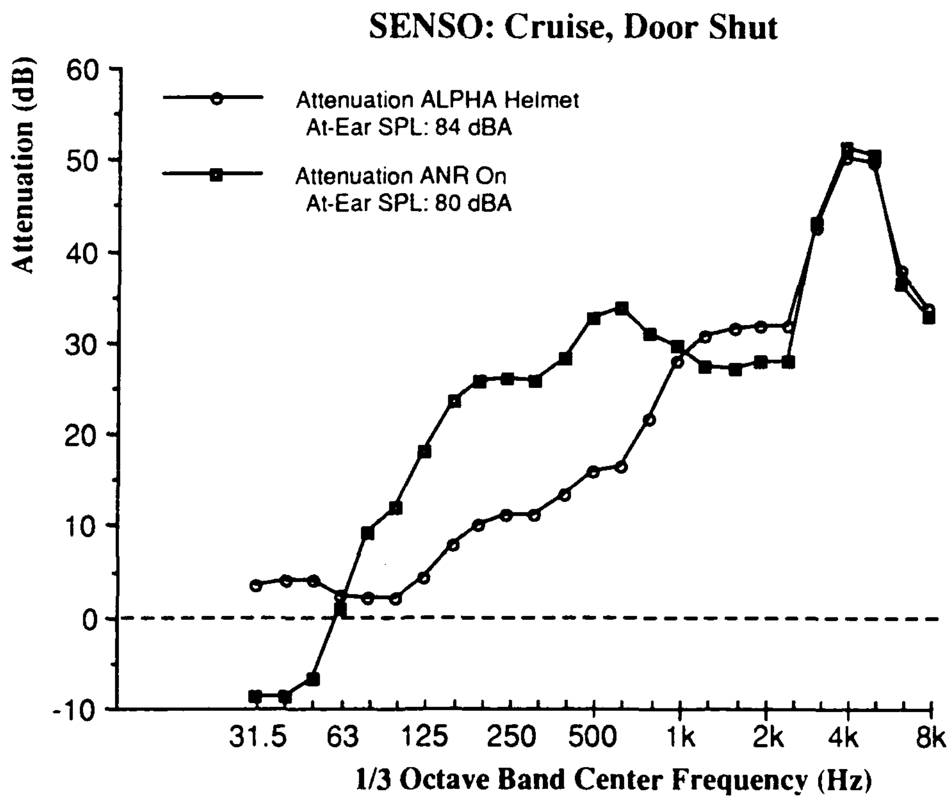

TACCO: Deceleration, Door Shut
Attenuation (dB)
60
50
40
30
20
10
0
-10
Attenuation ALPHA Helmet
At-Ear SPL: 78 dBA
Attenuation ANR On
At-Ear SPL: 74 dBA
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)


TACCO: Hover, Door Shut
Attenuation (dB)
60
50
40
30
20
10
0
-10
Attenuation ALPHA Helmet
At-Ear SPL: 77 dBA
Attenuation ANR On
At-Ear SPL: 72 dBA
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)

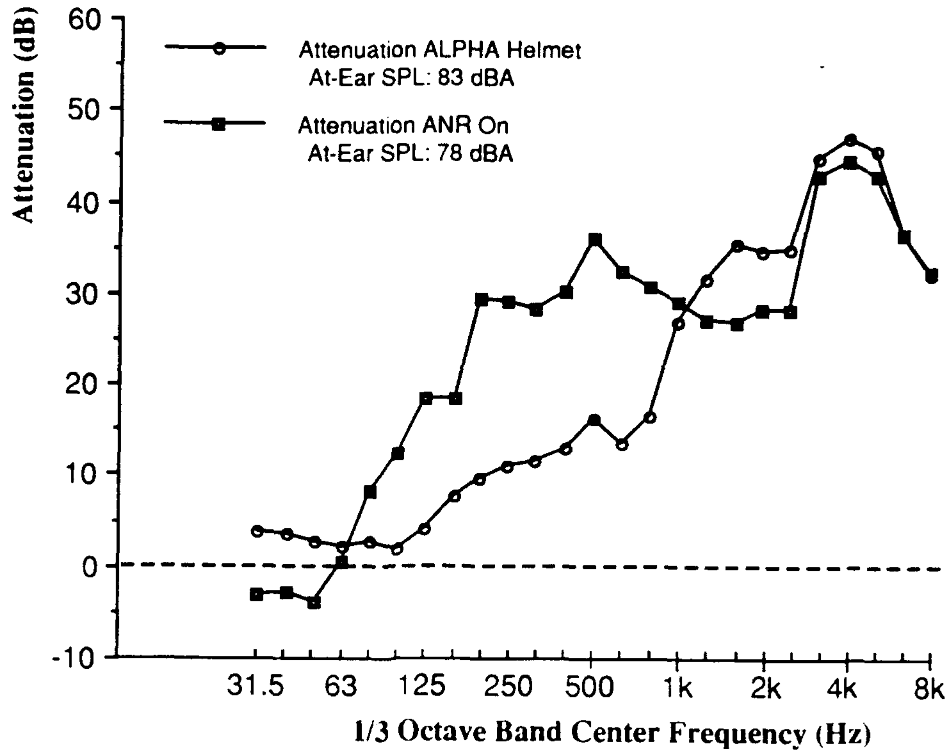


TACCO: Hover, Door Open
Attenuation (dB)
60
50
40
30
20
10
0
-10
Attenuation ALPHA Helmet
At-Ear SPL: 78 dBA
Attenuation ANR On
At-Ear SPL: 74 dBA
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)

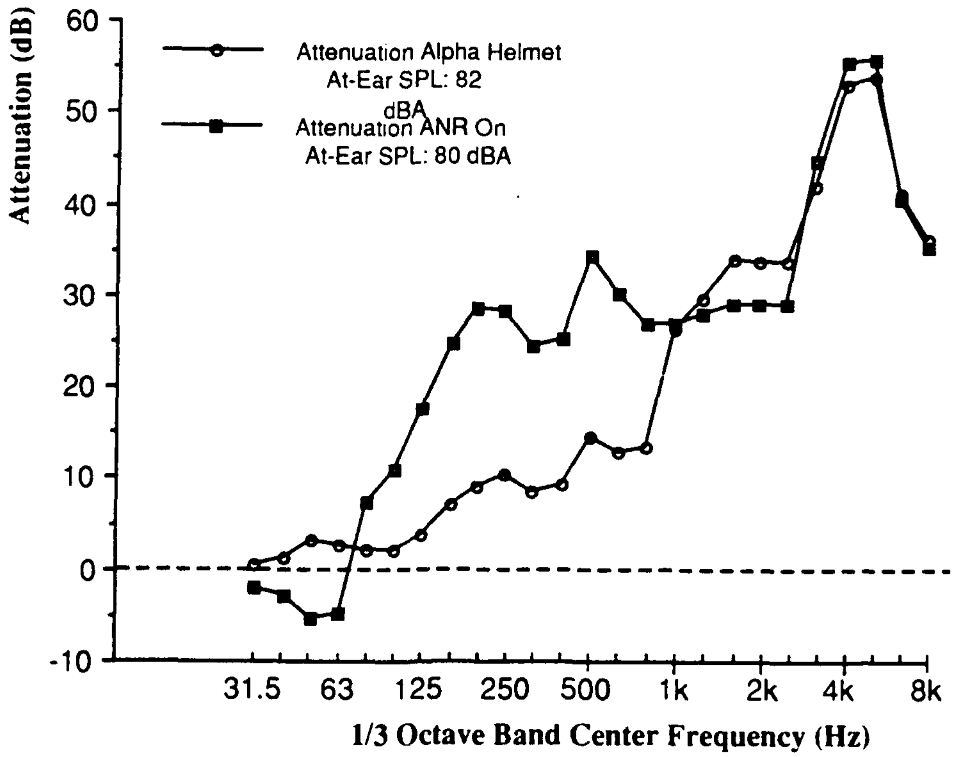

SENSO: Transition, Door Shut
Attenuation (dB)
Attenuation ALPHA Helmet
At-Ear SPL: 83 dBA
Attenuation ANR On
At-Ear SPL: 78 dBA
60
50
40
30
20
10
0
-10
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)


SENSO: Cruise, Door Shut
Attenuation (dB)
Attenuation ALPHA Helmet
At-Ear SPL: 84 dBA
Attenuation ANR On
At-Ear SPL: 80 dBA
60
50
40
30
20
10
0
-10
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)

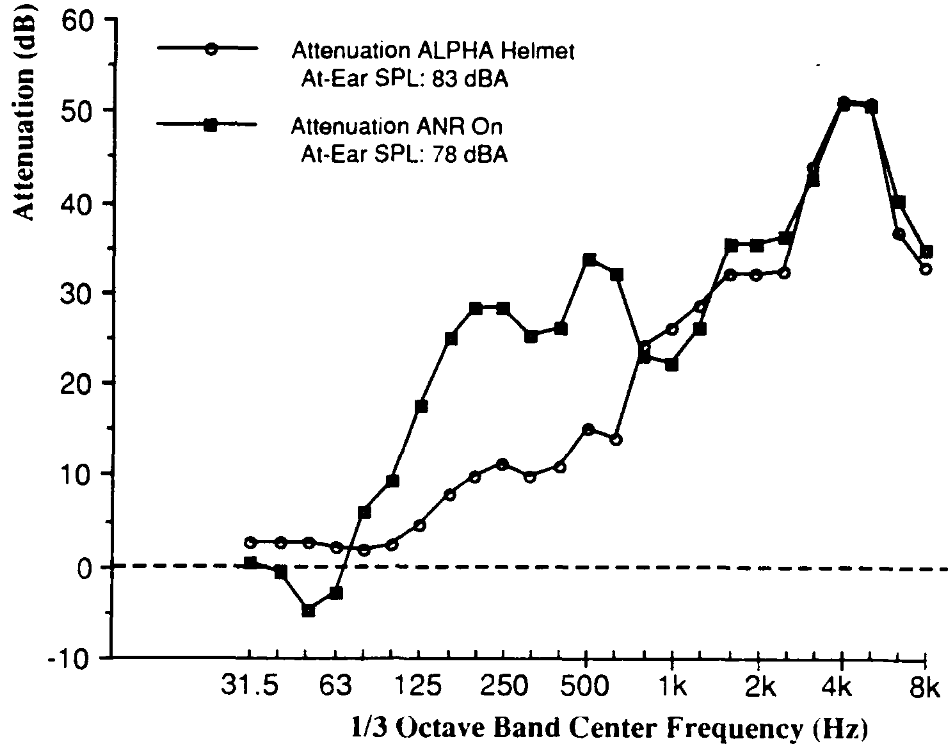
SENSO: Deceleration, Door Shut

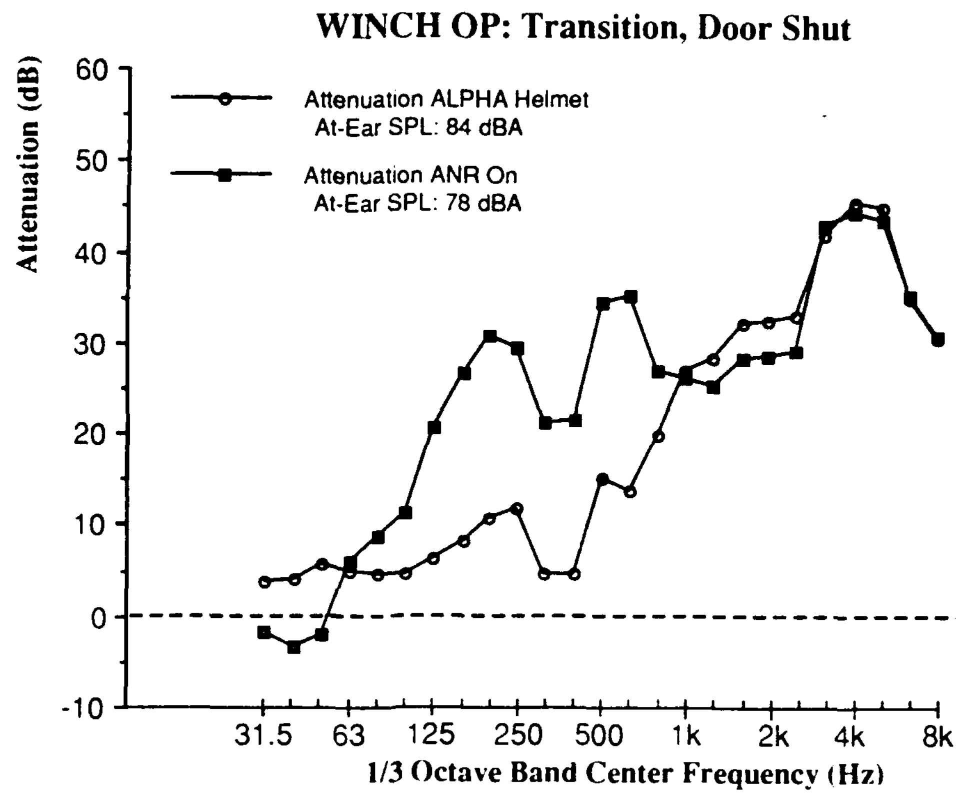


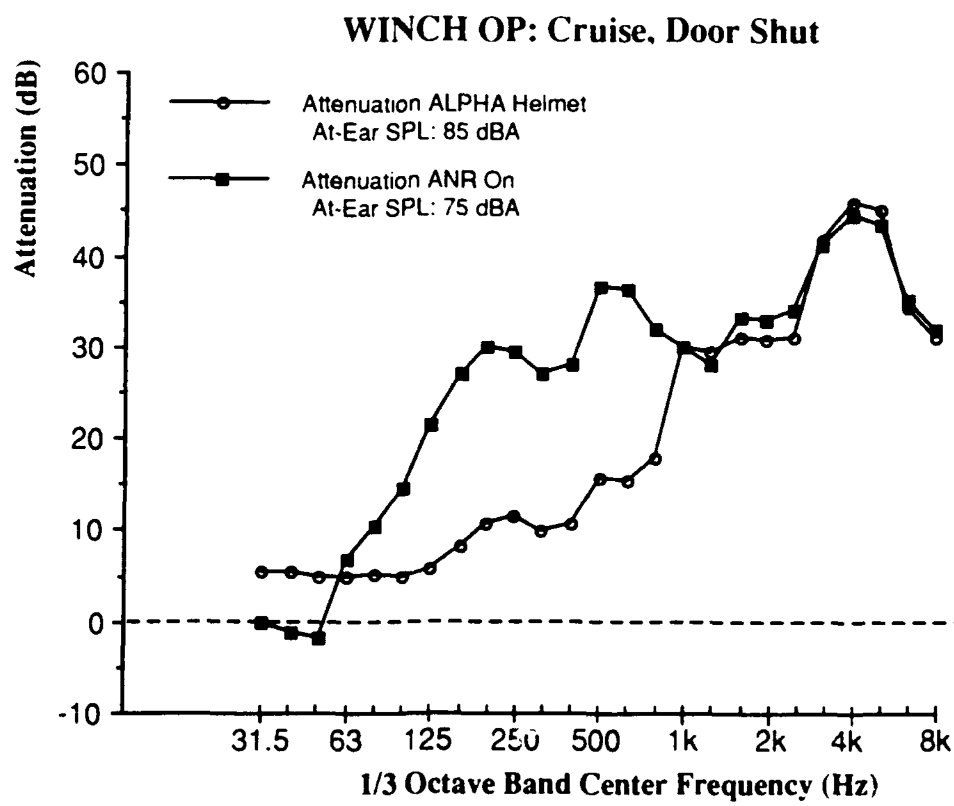
SENSO: Hover, Door Shut

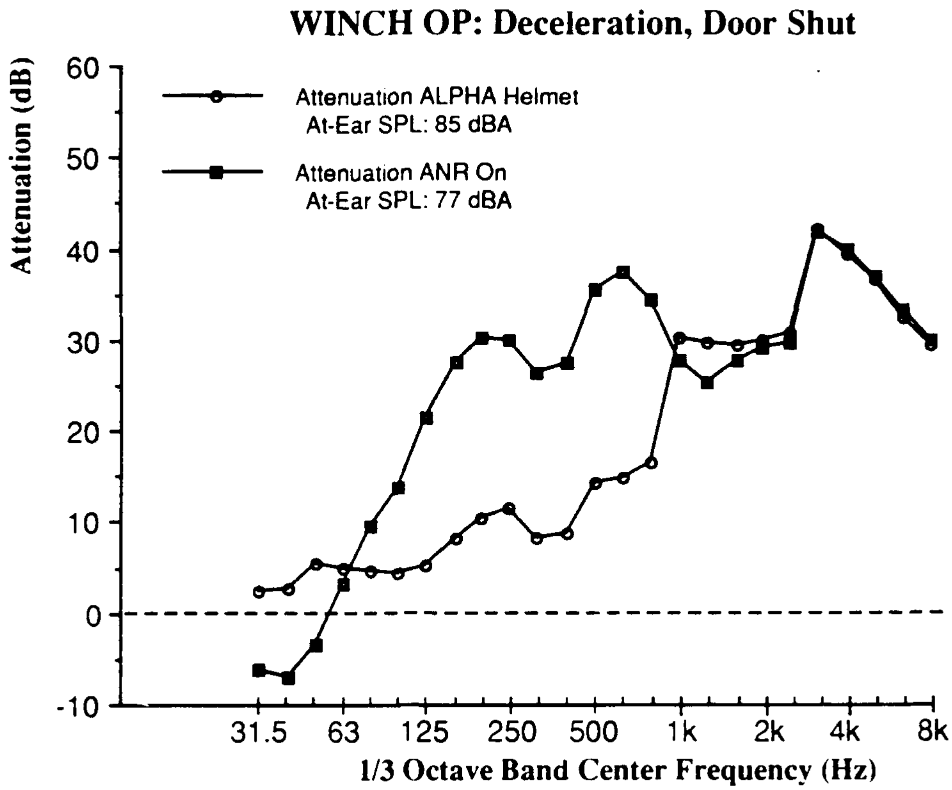


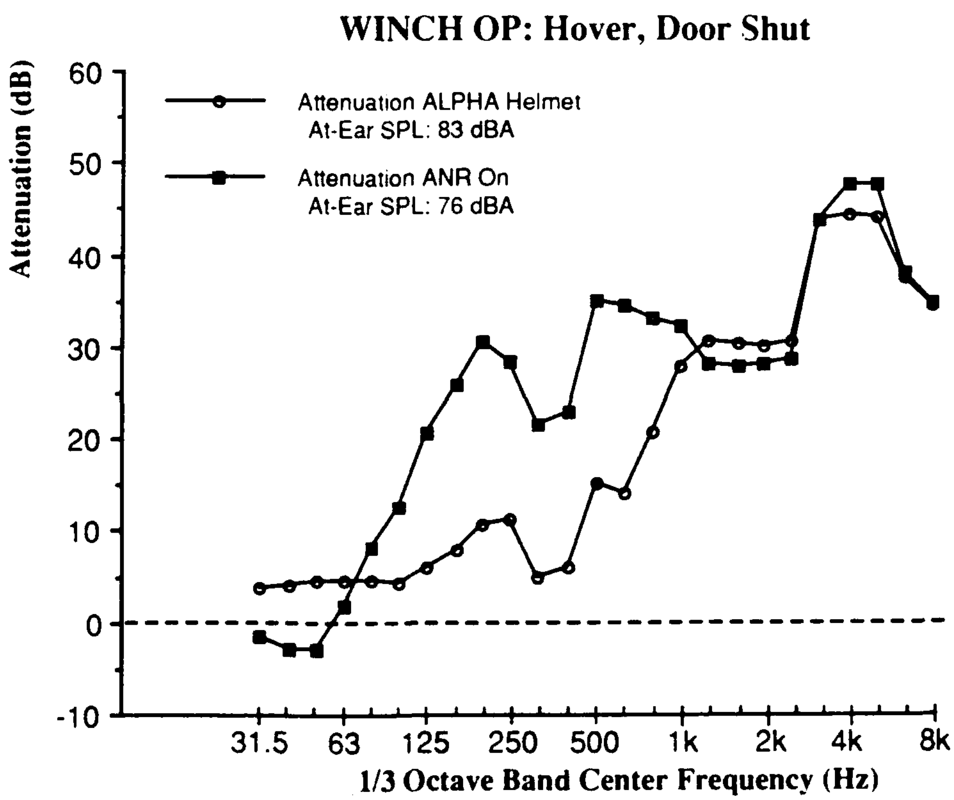
SENSO: Hover, Door Open

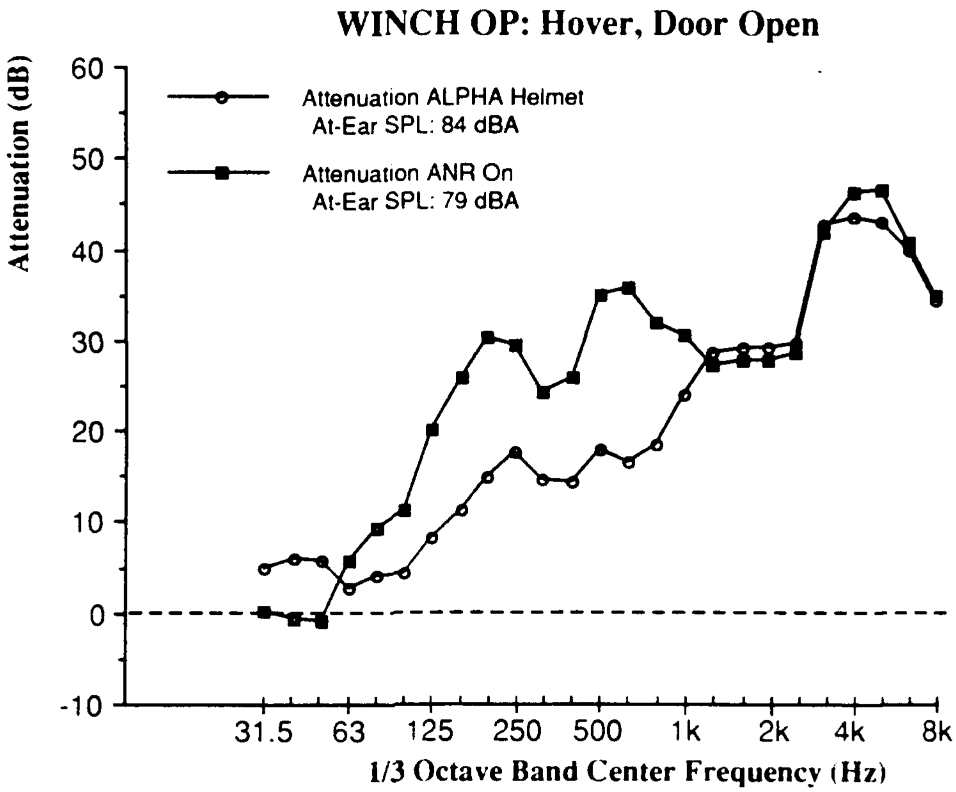



WINCH OP: Transition, Door Shut
Attenuation (dB)
60
50
40
30
20
10
0
-10
Attenuation ALPHA Helmet
At-Ear SPL: 84 dBA
Attenuation ANR On
At-Ear SPL: 78 dBA
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)


WINCH OP: Cruise, Door Shut
Attenuation (dB)
60
50
40
30
20
10
0
-10
Attenuation ALPHA Helmet
At-Ear SPL: 85 dBA
Attenuation ANR On
At-Ear SPL: 75 dBA
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)


WINCH OP: Deceleration, Door Shut
Attenuation (dB)
60
50
40
30
20
10
0
-10
Attenuation ALPHA Helmet
At-Ear SPL: 85 dBA
Attenuation ANR On
At-Ear SPL: 77 dBA
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)


WINCH OP: Hover, Door Shut
Attenuation (dB)
60
50
40
30
20
10
0
-10
Attenuation ALPHA Helmet
At-Ear SPL: 83 dBA
Attenuation ANR On
At-Ear SPL: 76 dBA
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)

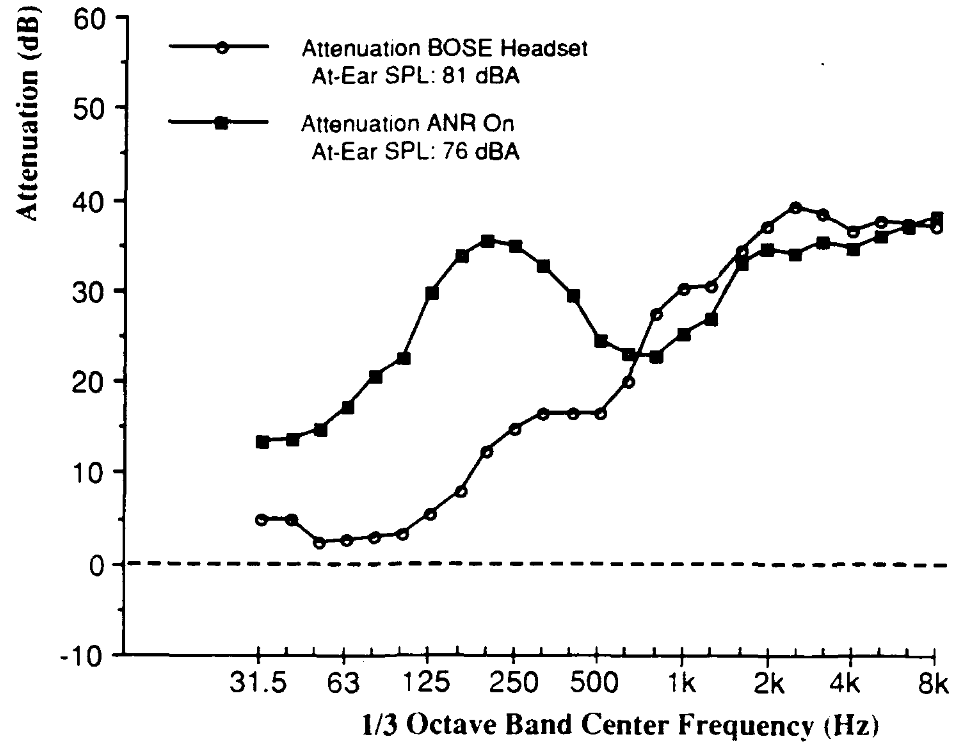


WINCH OP: Hover, Door Open
Attenuation (dB)
60
50
40
30
20
10
0
-10
Attenuation ALPHA Helmet
At-Ear SPL: 84 dBA
Attenuation ANR On
At-Ear SPL: 79 dBA
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)

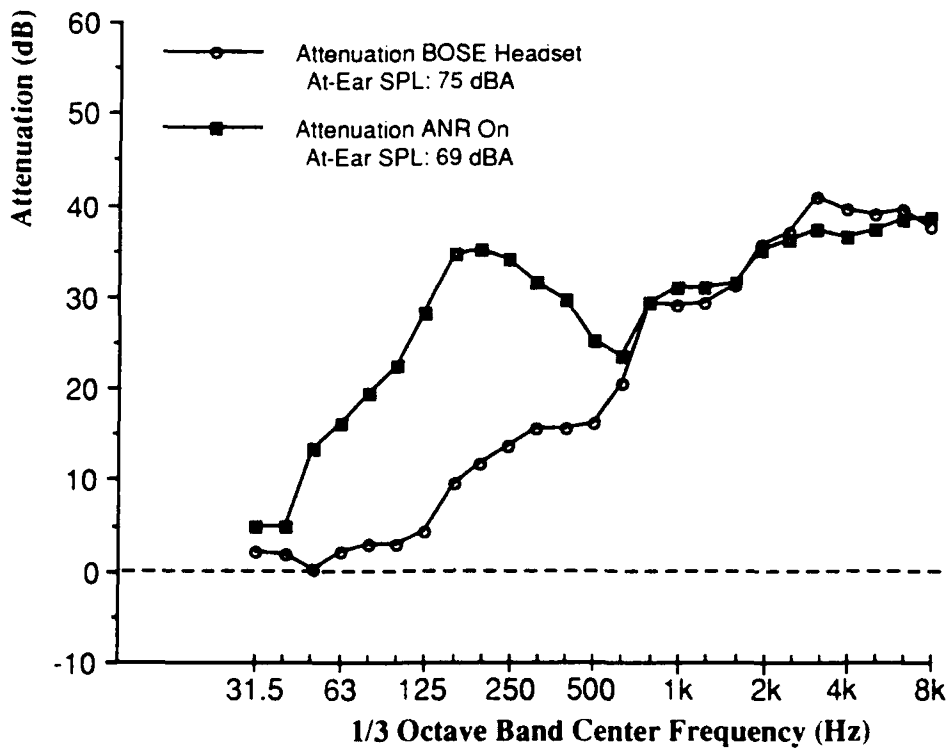
APPENDIX B

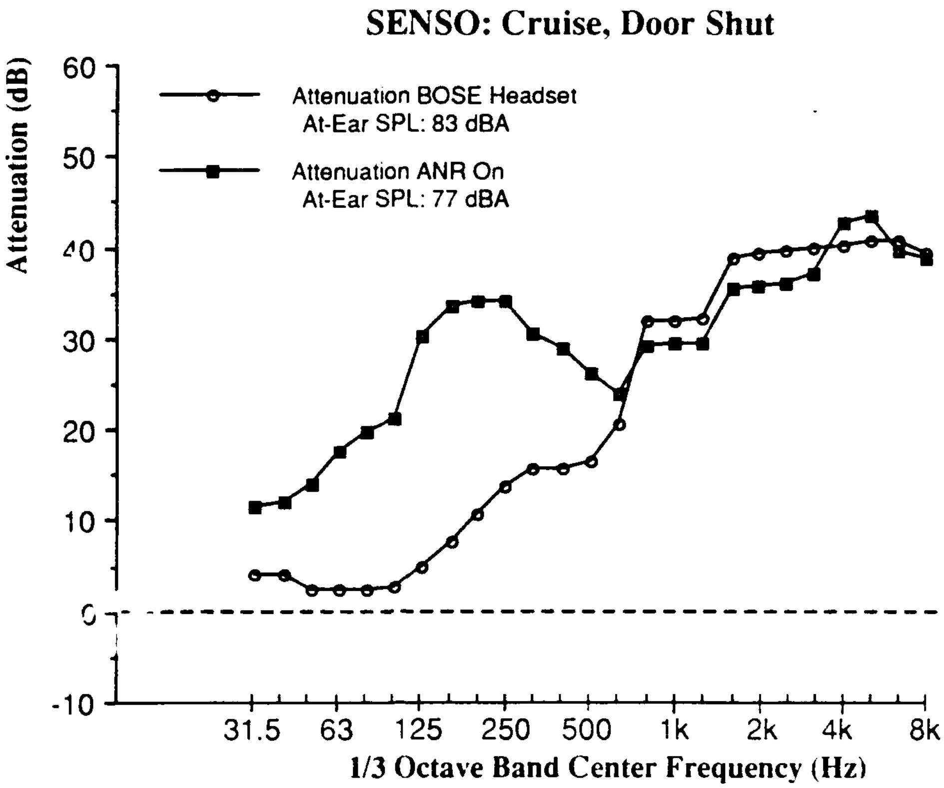
Attenuation provided by the BOSE headset and ANR System for each crew position and flight condition

TACCO: Cruise, Door Shut

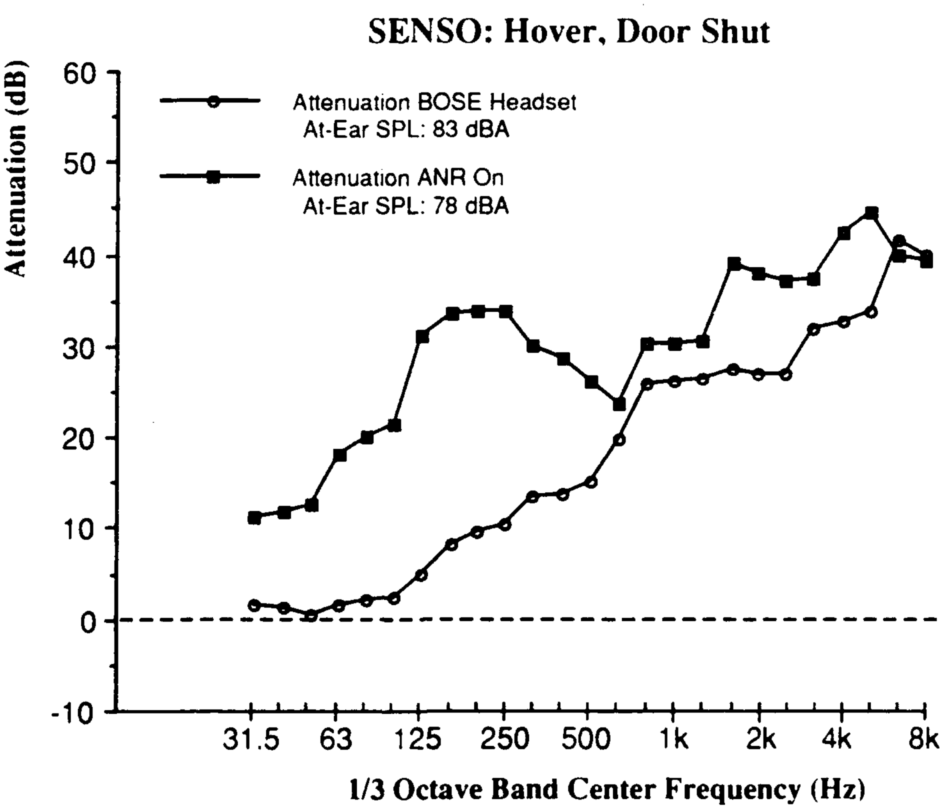


TACCO: Hover, Door Shut



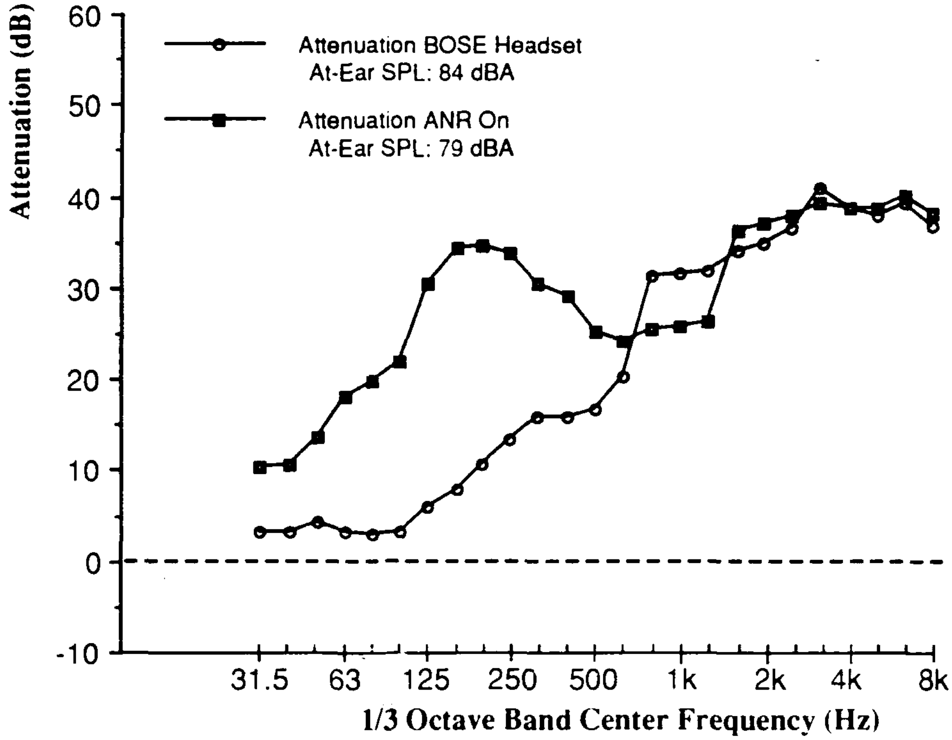


SENSO: Cruise, Door Shut
Attenuation (dB)
60
50
40
30
20
10
0
-10
Attenuation BOSE Headset
At-Ear SPL: 83 dBA
Attenuation ANR On
At-Ear SPL: 77 dBA
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)

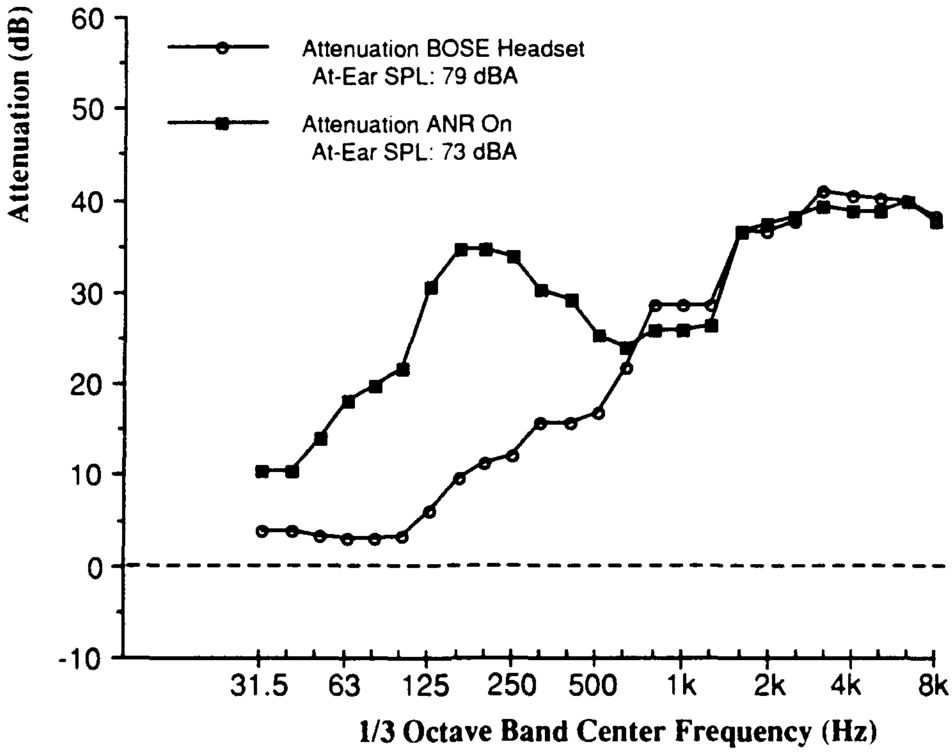


SENSO: Hover, Door Shut
Attenuation (dB)
60
50
40
30
20
10
0
-10
Attenuation BOSE Headset
At-Ear SPL: 83 dBA
Attenuation ANR On
At-Ear SPL: 78 dBA
31.5
63
125
250
500
1k
2k
4k
8k
1/3 Octave Band Center Frequency (Hz)

WINCH OP: Cruise, Door Shut



WINCH OP: Hover, Door Shut



APPENDIX C

A and C frequency weighting curves for $^{1}/_{3}$ octave bands

1/3 Octave Band Center Frequency	Curve A dB	Curve C dB
31.5	-39.4	-3.0
40	-34.6	-2.0
50	-30.2	-1.3
63	-26.2	-0.8
80	-22.5	-0.5
100	-19.1	-0.3
125	-16.1	-0.2
160	-13.4	-0.1
200	-10.9	0
250	-8.6	0
315	-6.6	0
400	-4.8	0
500	-3.2	0
630	-1.9	0
800	-0.8	0
1000	0	0
1250	0.6	0
1600	1.0	-0.1
2000	1.2	-0.2
2500	1.3	-0.3
3150	1.2	-0.5
4000	1.0	-0.8
5000	0.5	-1.3
6300	-0.1	-2.0
8000	-1.1	-3.0

DISTRIBUTION

AUSTRALIA

Department of Defence

Defence Central

Chief Defence Scientist
AS, Science Corporate Management
FAS Science Policy
(shared copy)

Director, Departmental Publications
Counsellor, Defence Science, London (Doc Data sheet only)
Counsellor, Defence Science, Washington (Doc Data sheet only)
S.A. to Thailand MRD (Doc Data sheet only)
S.A. to the DRC Kuala Lumpur (Doc Data sheet only)
Scientific Adviser, Defence Central
OIC TRS, Defence Central Library
Document Exchange Centre, DSTIC (8 copies)
Defence Intelligence Organisation
Librarian H Block, Victoria Barracks, Melb (Doc Data sheet only)
Director General - Army Development (NSO) (4 copies)
Industry Policy and Programs Branch, FAS

Aeronautical Research Laboratory

Director
Library
Chief - Air Operations Division
Author: R.B. King
D. A. Foran
J.G. Manton
R.A. Feik (ANL HTP-6)
B. Rebbechi

Materials Research Laboratory

Director/Library
Maritime Systems Division (Sydney)

Defence Science & Technology Organisation - Salisbury

Library

Navy Office

Navy Scientific Adviser
CO AMAFTU HMAS Albatross
DAWSC HMAS Albatross
CO SITU HMAS Albatross
RAN Tactical School, Library
RAN Enviromental Medicine Unit
Director Aircraft Engineering - Navy
Director of Naval Air Warfare
Director of Naval Architecture

Naval Support Command
    Superintendent, Naval Aircraft Logistics
Directorate of Aviation Projects - Navy
Director of Naval Supply - Aviation & Major Projects

Army Office
Scientific Adviser - Army
SMO Army Aviation Centre
DAVN

Air Force Office
Air Force Scientific Adviser
Aircraft Research and Development Unit
    Scientific Flight Group
    Library
Materiel Division Library
Director General Air Warfare Plans & Policy
OIC ATF, ATS, RAAFSTT, WAGGA (2 copies)
CO RAAF Institute of Aviation Medicine

HQ ADF
Director General Force Development (Air)

Statutory and State Authorities and Industry
Ansett Airlines of Australia, Library
Australian Airlines, Library
Qantas Airways Limited
Civil Aviation Authority
Gas & Fuel Corporation of Vic., Manager Scientific Services
Ampol Petroleum (Vic) Pty Ltd, Lubricant Sales & Service Mgr
BHP, Melbourne Research Laboratories
BP Australia Ltd, Library
Police Air Wing
Bureau of Air Safety Investigations

Universities and Colleges
Adelaide
    Barr Smith Library
    Professor Mechanical Engineering

Flinders
    Library

LaTrobe
    Library

Melbourne
    Engineering Library

Monash
    Hargrave Library
    Head, Materials Engineering

Newcastle
Library
Professor R. Telfer, Institute of Aviation

New England
Library

Sydney
Engineering Library
Head, Dept of Aero Engineering

NSW
Physical Sciences Library
Head, Mechanical Engineering
Library, Australian Defence Force Academy

Queensland
Library

Tasmania
Engineering Library

Western Australia
Library
Head, Mechanical Engineering

RMIT
Library
Mr M.L. Scott, Aerospace Engineering

University College of the Northern Territory
Library

CANADA

DCIEM
NRC
Dr M. Sinclair, National Leader TTCP HTP-6

FRANCE
ONERA

INDIA
CAARC Coordinator Human Factors
National Aeronautical Laboratory, Information Centre

ISRAEL
Technion-Israel Institute of Technology

JAPAN

National Aerospace Laboratory

NETHERLANDS

National Aerospace Laboratory (NLR), Library

NEW ZEALAND

Defence Scientific Establishment, Library
RNZAF

Universities

Canterbury

Head, Mechanical Engineering
Library

SWEDEN

Aeronautical Research Institute, Library
Swedish National Defense Research Institute (FOA)

UNITED KINGDOM

CAARC Coordinator Human Factors
Defence Research Agency (Aerospace)
Mr A.F. Jones, UK National Leader, TTCP HTP-6
Farnborough, Dr G. Rood
CO RAF IAM

Universities and Colleges

Southampton
Library

Cranfield Inst. of Technology
Library

Imperial College
Aeronautics Library

UNITED STATES OF AMERICA

Naval Air Test Center, US Army Aeromedical Research Lab.
US Army Aviation, Aviation Systems Command
Naval Aerospace, Medical Research Center
Mr W. G. Bousman, USNL, TTCP HTP-6
J.J. Coy, Mechanical Systems Technology Group, NASA Lewis

SPARES (10 COPIES)

TOTAL (121 COPIES)

AL 149 DEPARTMENT OF DEFENCE

DOCUMENT CONTROL DATA

PAGE CLASSIFICATION
UNCLASSIFIED

PRIVACY MARKING

1a. AR NUMBER	1b. ESTABLISHMENT NUMBER	2. DOCUMENT DATE	3. TASK NUMBER
AR-007-077	ARL-TR-9	NOVEMBER 92	NAV90/023

4. TITLE
IN-FLIGHT EVALUATION OF NOISE LEVELS AND ASSESSMENT OF ACTIVE NOISE REDUCTION SYSTEMS IN THE SEAHAWK S-70B-2 HELICOPTER

5. SECURITY CLASSIFICATION
(PLACE APPROPRIATE CLASSIFICATION IN BOX(S) IE. SECRET (S), CONF. (C) RESTRICTED (R), LIMITED (L) UNCLASSIFIED (U)).

U	U	U
DOCUMENT	TITLE	ABSTRACT

6. NO. PAGES
38

7. NO. REFS.
7

8. AUTHOR(S)
R.B. KING
D.A. FORAN

9. DOWNGRADING/DELIMITING INSTRUCTIONS
Not applicable.

10. CORPORATE AUTHOR AND ADDRESS

AERONAUTICAL RESEARCH LABORATORY
AIR OPERATIONS DIVISION
506 LORIMER STREET
FISHERMENS BEND VIC 3207

11. OFFICE/POSITION RESPONSIBLE FOR:

SPONSOR NAVY
SECURITY -
DOWNGRADING -
APPROVAL CAOD

12. SECONDARY DISTRIBUTION (OF THIS DOCUMENT)

Approved for public release.

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DSTIC, ADMINISTRATIVE SERVICES BRANCH, DEPARTMENT OF DEFENCE, ANZAC PARK WEST OFFICES, ACT 2601

13a. THIS DOCUMENT MAY BE ANNOUNCED IN CATALOGUES AND AWARENESS SERVICES AVAILABLE TO ....

No limitations.

13b. CITATION FOR OTHER PURPOSES (IE. CASUAL ANNOUNCEMENT) MAY BE [X] UNRESTRICTED OR [ ] AS FOR 13a.

14. DESCRIPTORS
S70B helicopters
Noise reduction
Acoustic attenuation

15. DISCAT SUBJECT CATEGORIES
010301
2001

16. ABSTRACT
Cabin and at-ear sound spectra in the S-70B-2 at various crew positions and flight conditions were measured in order to determine the noise attenuation properties of the ALPHA helmet and the effectiveness of active noise reduction (ANR) systems developed by the Defence Research Agency - Aerospace Division (formerly the Royal Aerospace Establishment) and the BOSE Corporation. Results show that if newly proposed hearing conservation guidelines are adopted, aircrew wearing the ALPHA helmet would require additional attenuation devices. It is recommended that an ANR system be incorporated into the S-70B-2 as such a system would allow realistic flight duration to be maintained, improve voice communication, and reduce aircrew fatigue.

PAGE CLASSIFICATION
UNCLASSIFIED
PRIVACY MARKING

THIS PAGE IS TO BE USED TO RECORD INFORMATION WHICH IS REQUIRED BY THE ESTABLISHMENT FOR ITS OWN USE BUT WHICH WILL NOT BE ADDED TO THE DISTIS DATA UNLESS SPECIFICALLY REQUESTED.

16. ABSTRACT (CONT).

17. IMPRINT

AERONAUTICAL RESEARCH LABORATORY, MELBOURNE

18 DOCUMENT SERIES AND NUMBER	19. COST CODE	20. TYPE OF REPORT AND PERIOD COVERED
Technical Report 9	73 734F	

21. COMPUTER PROGRAMS USED

22. ESTABLISHMENT FILE REF.(S)

23. ADDITIONAL INFORMATION (AS REQUIRED)